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DEC 77 R E HORTON, J E MCCARTY F33615-73-C-5171

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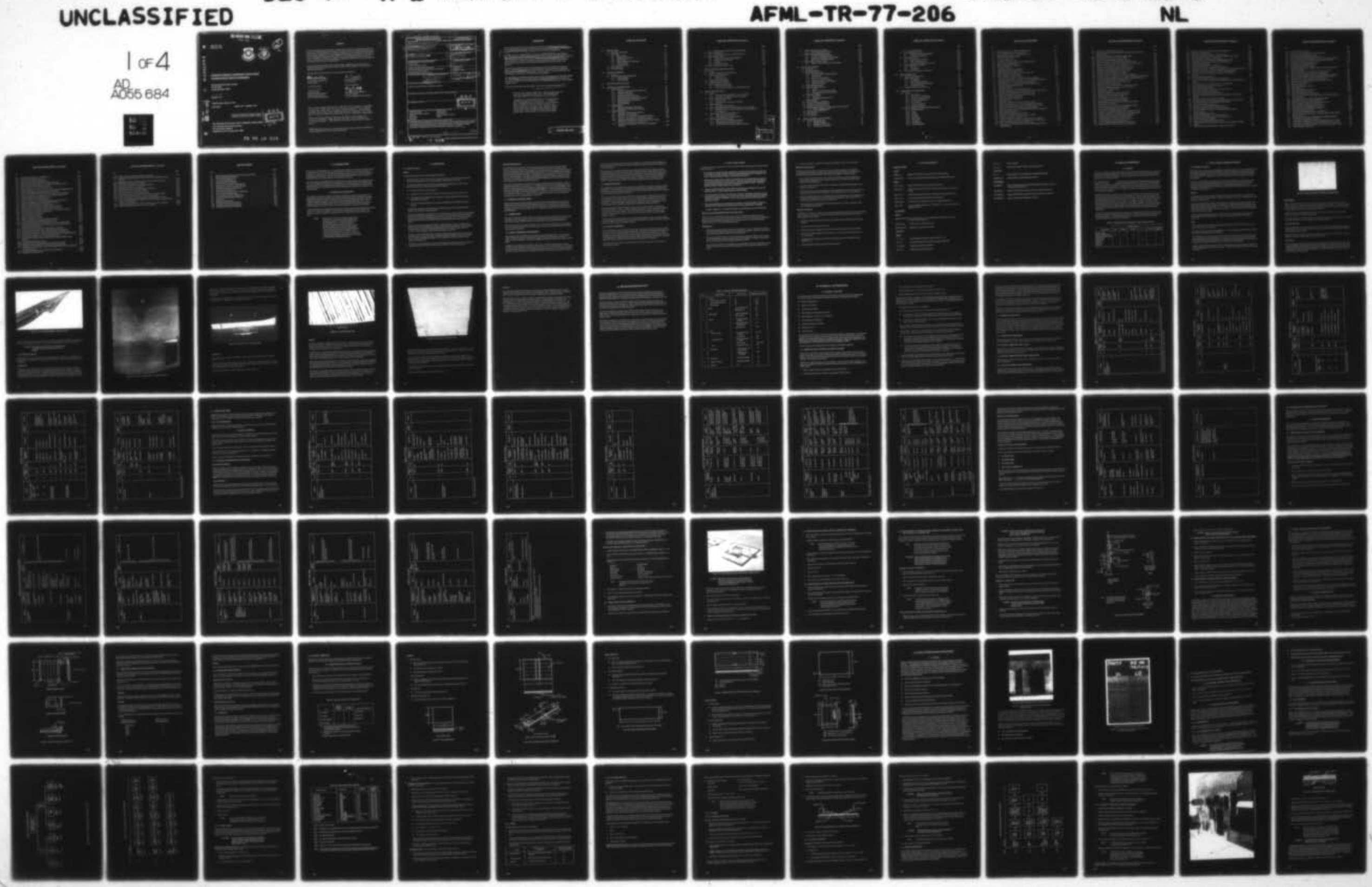

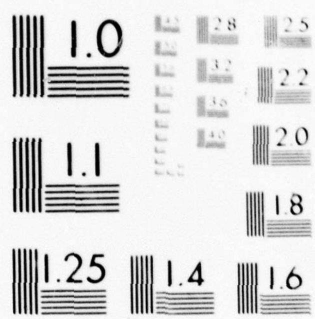

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ADHESIVE BONDED AEROSPACE STRUCTURES STANDARDIZED REPAIR HANDBOOK

Boeing Commercial Airplane Company
P.O. Box 3707
Seattle, Washington 98124

December 1977

Technical Report AFML-TR-77-206

Final Report October 1973 - September 1978

AIR FORCE MATERIALS AND FLIGHT DYNAMICS LABORATORIES
Air Force Wright Aeronautical Laboratories
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

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This report has been reviewed by the Information Office, (ASD/OIP), and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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While certain bonding materials are identified in this report as preferred, this does not signify that these are the only materials which are capable of being used in the repair of adhesive bonded structure. Other bonding materials, particularly those developed since the conclusion of the study, may have equal or superior qualities when tested to individual requirements.

Lists of ancillary materials have been included in this document for information purposes. These materials have been found satisfactory for the intended purposes. Other materials from other sources may be equal or better.

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This handbook is the culmination of a five-phase program to develop standardized repair procedures for adhesively bonded aircraft structures. It recommends repair materials and processing methods. It identifies repair procedures for both small and large size repairs. It additionally includes information on equipment and tools and nondestructive inspection techniques.

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FOREWORD

This handbook represents the final culmination of the work accomplished during five phases of contract F33615-73-C-5171, *Adhesive Bonded Aerospace Structures Standardized Repair Handbook*, by the Boeing Commercial Airplane Company, P.O. Box 3707, Seattle, Washington.

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The Phase I report was a limited distribution document. The other phase reports are as follows: Phase II-AFML-TR-75-158, Phase III-AFML-TR-76-65, Phase IV-AFML-TR-76-201/AFFDL-TR-76-131. These phase reports contain the material and discussions that led to this Handbook. Further work is being performed to optimize the phosphoric acid non-tank anodize method (PANTA) and to provide additional adhesives data. This data will be submitted later as an amendment to this Handbook.

62102F

The work was accomplished under the joint sponsorship of the Air Force Materials Laboratory (Project 7381/Task 06) and the Air Force Flight Dynamics Laboratory (Project 1368/Task 02). 62201F Mr. W. Scardino, AFML/MXE of the Materials Laboratory, and Mr. H. Croop, AFFDL/FBS of the Flight Dynamics Laboratory, were the Air Force project engineers.

Mr. J. E. McCarty was the Boeing program manager, and Mr. R. E. Horton was the principal investigator. Other Boeing personnel who made technical contributions to the program and their areas of activity are as follows: M. C. Locke, Materials; M. L. Satterthwait, Manufacturing; and B. D. Parashar, Quality Control.

This work was performed in the period from 1 October 1973 through 30 September 1977.

The Naval Air Systems Command (Mr. John Gurtowski) and the Naval Air Development Center (Mrs. Gladys Hargreaves) furnished support and coordination for this program.

Background data and information for this program were furnished during facility visits by Northrup, Rohr, Lockheed/Burbank, Lockheed/Ga., Bell Helicopter, General Dynamics Ft. Worth, United Airlines, Pan American Airlines, San Antonio Air Logistics Center, Warner Robins ALC, Sacramento ALC, Naval Air Rework Facilities at Cherry Point and North Island, Army Repair Depot Corpus Christi, and Picatinny Arsenal.

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1.0 INTRODUCTION

The purposes of this handbook are (1) to provide standard methods for the repair of adhesive-bonded aircraft structure and (2) to identify the materials that are suitable for various aircraft operating environments. The objective in selecting the methods and materials has been to restore the part to its original strength and durability. The use of these methods is recommended to promote utilization of standard repair procedures regardless of the particular aircraft type.

The surface preparation methods presented here have been selected as the best of the methods evaluated. Items considered in the selection were suitability for use in the field and depot, strength, and long time resistance of the bondline to various environments. The materials that were selected were chosen because they are currently being successfully used and because their service performance has been satisfactory.

1.1 CONTENTS AND LIMITATIONS

This handbook contains a description of standard methods for the repair of bonded-sandwich- and metal-laminate-type aircraft construction. The items covered include prerepair damage evaluation, preparation of the part for repair, a description of the materials, and repair procedures. The repair methods designated in section 6.0 will cover the majority of small damage repair cases. These methods have been selected from those used in the current aircraft repair technical orders (T.O.'s). Large area repairs are covered in section 7.0. Postrepair inspection instruction is also included.

A direct substitution can usually be made between the methods and materials presented here and those in the T.O. In general, an equivalency or improvement in repair quality can be expected. The handbook is, however, intended to supplement but not to supersede the specific aircraft's repair T.O.

NOTE: The aircraft's T.O. must be consulted regarding such information as repair size and weight limitations and operating environment. The repair limitations have been established by the manufacturer based on criticality of the specific aircraft. Violation of these may cause problems such as operational difficulties with control surface dynamics or structural deficiencies in critical components or structural failure. Deviations from these limitations, extension of the methods, or substitution of materials shall be defined or authorized by the responsible engineering authority.

1.2 INSTRUCTIONS

1.2.1 MANUAL USAGE

General

The general procedures for use of this handbook are as follows:

1. Determine the size of defect or the extent of damage. Procedures to be used for damage evaluation are covered in section 2.0. They are described in more detail in section 10.0.

2. Review the individual aircraft T.O. for specific information and instructions for the type of aircraft being repaired. These typically include the following:

   - Structural criticality of the damaged area
   - Limitations such as the maximum weight that the repair may add to the structure, etc
   - Identification of the materials used in construction of the damaged part and the service temperature requirements
   - The type of repair method that is recommended depending on the location and type of damage.

   The degree of substitution of the methods and materials presented in this handbook shall be defined by the responsible engineering agency.

3. Determine the appropriate repair method. If the damaged area is relatively small, the recommended repair method will be typically defined in section 6.0. If the damage is beyond the small repair limits, then a large repair or rebuilding procedure may be required. This is covered in section 7.0. Any limitations on the use of these methods will be defined by the responsible engineering agency.

4. Obtain the materials and equipment necessary to make the repair. These are listed for small repairs in section 6.0 preceding the description of each specific repair method. They are defined for large repairs in section 7.0. Specific materials that are to be used are further defined in section 4.0. Tools, equipment, and facilities are described in section 8.0.

5. Prepare the area for the bonded repair. The repair method procedures describe how the damage should be removed and how the surfaces should be prepared for bonding. Pay particular attention to caution notes regarding handling of surface preparation chemicals and protection of prepared bonding surfaces

6. Complete the repair procedures. Instructions for bonding, for subsequent surface protection and sealing and instructions for inspection are given in sections 4.0 and 10.0, respectively.

Other Information Sources

The information in this handbook covers standard repair practices for adhesive-bonded aircraft structure. Information that is specific to the particular aircraft model such as repair limitations, construction materials, and service temperatures are covered in the aircraft's repair manual. Standard practices for structural repair, in general, are set forth in T.O. 1-1A-1, *General Manual for Structural Repair*, and other manuals of that series. This information is not repeated here. It should be utilized, however, where applicable. The methods and materials specified in this handbook should be used unless they are not applicable or conflicts exist between this handbook and the authorized manuals. *In the latter case, the authorized manual shall govern.*

Other pertinent information is available in various military handbooks and specifications. A list of applicable specifications is given in section 1.4. Design properties of metals, including those for sheet, plate, bar, and extrusions and for mechanically fastened joints, may be found in MIL-HDBK-5. The properties of fiberglass laminates may be found in MIL-HDBK-17. Analysis and design methods for sandwich construction are included in MIL-HDBK-23. Properties of core materials can best be found in the appropriate MIL specs, e.g., MIL-C-7438 for aluminum honeycomb core. Other applicable specifications for core materials are listed in section 4.0.

1.2.2 PERSONNEL QUALIFICATIONS

Repair personnel must be fully qualified in the preparation of repair materials and in the repair of bonded honeycomb sandwich and metal laminate construction. Inspectors must be qualified and skilled in the use of the repair and inspection equipment specified. Qualification requirements for bonding technicians are covered in MIL-A-83377. Qualification of inspection personnel shall be per MIL-STD-410D.

1.2.3 WORKMANSHIP

The ability of the bonded repair to perform satisfactorily for the remaining life of the aircraft is very dependent on how well the repair is made. It is essentially that the procedures outlined in this handbook be carefully followed and that all repairs be done in a good workmanship manner.

Honeycomb structure can be extremely fragile. Special care may be required to prevent damage to the surrounding structure during the repair operation. Protective covering shall be placed around the repair area where applicable.

1.2.4 REPAIR ATMOSPHERIC ENVIRONMENT

Requirements for the bonding repair environment are specified in MIL-A-83377. The area where surface cleaning of the parts is done should be isolated from operations that generate dust, oil vapors, or other contaminants. All personnel handling cleaned parts shall wear clean, white, lint-free gloves.

Immediately after cleaning, parts should be moved into a controlled atmosphere area for bond assembly. If the cleaning and controlled bonding areas are not in the same proximity, after cleaning, the parts should be sealed in noncontaminating wrapping for transfer to the controlled atmosphere layup area. The environment in the controlled area shall be as specified in the previously referenced

specification. Operations that generate dust or other airborne contaminants in the controlled area, such as sanding or grinding, should be forbidden. Similarly, smoking or eating in the controlled area should be prohibited.

Where practical, it is recommended that parts be removed from the aircraft for repair in the shop. It is recognized, however, that some repairs will of necessity be made on the aircraft. In these cases, special care must be taken to prevent the cleaning solutions from contacting surrounding surfaces, *especially the surfaces of high strength steels*, or from entering crevices. Precautions regarding contamination of the repair area during and subsequent to cleaning also apply. Bonding of the part should be completed as soon as possible after cleaning to minimize subsequent contamination.

1.2.5 REPAIR MATERIALS

All materials used in the bonded repair shall conform to applicable Government, or other acceptable, specifications. Care must be taken to ensure that materials requiring refrigeration maintain proper temperature levels during transit and until placed in receiving storage. During storage, proper temperature and humidity controls must be provided.

Upon receipt, it shall be ensured that materials meet minimum specification requirements. This can be accomplished by performing in-house tests or by requiring that the supplier furnish certified qualifying test results. A guide to those types of tests that should be conducted in-house is given in section 4.6. All material shall be clearly marked to indicate its storage or expiration date. Outdated material shall be requalified or discarded per the applicable control specification.

Instructions regarding material handling and storage must be carefully followed. Refrigerated polymeric materials, e.g., adhesives, potting compounds, sealants, etc., must be allowed to stabilize at room temperature before opening. The material should be hermetically sealed before being returned to storage and the out-time recorded. Special precautions should be taken in handling flammable materials.

Cleaned and primed metal details, to be stored rather than immediately used in a bonded assembly, should be wrapped in oil free Kraft paper, black polyethylene film, or a similar material as a protection from deterioration caused by ultraviolet exposure.

1.2.6 QUALITY ASSURANCE

An effective quality assurance program should be conducted concurrent with the repair procedures to assure satisfactory end-item strength and durability. Materials and material handling should meet requirements in the applicable specifications including proper storage and adherence to shelf life stipulations. Processing steps should be carefully followed with emphasis on those items concerned with maintenance of a properly prepared bonding surface and good prefit of part details. Processing procedures should be checked at critical steps to assure specification conformance.

After completion, the quality of the repair should be evaluated for approval by the responsible maintenance personnel.

1.3 SAFETY PRECAUTIONS

The following safety precautions must be strictly observed while making repairs or removing moisture from the structure:

1. **If the repair is to be made while the component is on the aircraft, the aircraft and repair cart, if used, shall be statically grounded. Only approved explosionproof electrical equipment shall be used. Electrical equipment shall be grounded while in operation.**

2. **When repairs are being made to a hole over a fuel tank area, the fuel tank shall be purged and checked continuously for an explosive mixture. The repair area shall be kept well ventilated. Special precautions should be taken while working with flammable materials. Firefighting equipment shall be available during the repair operation.**

3. **Adequate ventilation shall be provided during the mixing and use of adhesives, solvents, and cleaning solutions. Avoid breathing fumes from these materials.**

4. **Always add acid to the water. Never add water to the acid. The solutions should not come in contact with the skin and clothing. In case of contact, they should be washed off immediately with generous amounts of cold water. Always wear eye protection and rubber gloves when using these solutions.**

5. **Wear heat insulating gloves when handling hot equipment and repair materials. Respirators should be worn for operations creating excess dust, such as sanding metal or fiberglass.**

6. CLOSELY OBSERVE ALL APPLICABLE BASE AND FEDERAL SAFETY STANDARDS.

SPECIAL NOTES CONCERNING THE USE OF SOLVENTS

Because of the continued necessity to use solvents while accomplishing bonded repairs, their potential problems as a danger to health and the incidence of fire must be given special consideration. Pertinent general information concerning the use of solvents is given in subsequent paragraphs. Refer to T.O. 42A1-1-3 for any additional information.

Health Hazards:

1. If absorbed through the skin, solvents may cause dermatitis. They can dissolve natural skin oils and result in drying and cracking of the skin, rendering it susceptible to infection. Solvents may cause irritation and allergic reaction to sensitive individuals.

2. If vapors are inhaled, solvents can cause mild symptoms of headache, fatigue, nausea, or visual and mental disturbances during prolonged and repeated exposures to moderate concentrations. Severe exposures may result in unconsciousness and even death.

   Solvent vapors can also act as an anesthetic, or cause irritation of the eyes or respiratory system. They can result in blood, liver and kidney damage if the solvents are specific agents for these organs.

3. Solvents are harmful if swallowed. Symptoms may be similar to those of vapor inhalation.

Minimize Personal Exposure

Personal contact with the liquid or inhalation of vapors should be minimized or eliminated by engineering techniques such as enclosure of the process or equipment, isolation of operations and use of local exhaust ventilation and protective clothing and equipment. Personnel should:

1. Avoid solvent contact with the skin. Wear rubber or neoprene gloves when handling liquid solvents. Other equipment, such as impervious aprons, sleeves, coveralls, and boots, may be necessary in certain operations.
2. Avoid eye exposure to liquid solvent, vapor or overspray, by wearing chemical goggles or other approved eye protection.
3. Avoid using solvents as skin cleansing agents. If solvent contacts the skin, wash the affected area immediately with soap and water and apply a skin conditioning cream, lotion or ointment.
4. Avoid breathing solvent vapors. Use solvents only in well ventilated areas. Use respirators such as the chemical cartridge type, gas masks or airline full-face respirators where there is a lack of engineering control and high vapor concentrations exist.
5. Avoid using solvents for unauthorized or unapproved purposes. Use only for purposes called out in appropriate specifications.

Minimize Fire Hazards

To eliminate or minimize the danger of fire and consequent destruction of life and property, flammable solvents should be used only in areas approved and with methods recommended by the local fire safety authority. These include:

1. All flames, smoking, sparks and other sources of ignition must be eliminated from areas using solvents.
2. Non-spark producing tools should be used.
3. Clothing or processes creating static electricity should be eliminated or properly grounded.
4. All electrical equipment (lights, motors, wiring, etc.) must meet the electrical and fire codes for such locations.
5. Flammable solvents should be kept in closed containers and only in quantities to satisfy immediate use.
6. Provide adequate ventilation to prevent buildup of vapors.

1.4 LIST OF REFERENCES

SPECIFICATIONS

Federal

MMM-A-132	Adhesive, Heat Resistant, Airframe Structural, Metal to Metal
FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment

Military

MIL-A-25463	Adhesive, Metallic Structural Sandwich Construction
MIL-A-83376	Adhesive Bonded Aluminum Honeycomb Sandwich Structures, Acceptance Criteria
MIL-A-83377	Adhesive Bonding (Structural) for Aerospace Systems, Requirements for
MIL-C-7438	Core Material, Aluminum for Sandwich Construction
MIL-M-38780	Specification for Nondestructive Inspection Application Manuals
MIL-I-6870	Inspection Program Requirements, Nondestructive: for Aircraft and Missiles Materials and Parts

STANDARDS

Military

MIL-STD-768(ASG)	Instructions for Repair of Aircraft and Weapons Sandwich Structures. Part II–Metal Construction
MIL-STD-860	Fokker Ultrasonic Adhesive Bond Test
MIL-STD-410D	Qualification of Inspection Personnel

MANUALS

Military

T.O. 1-1A-1	General Manual for Structural Repair (Navair 01-1A-1)
T.O. 1-1-2	Corrosion Prevention and Control for Aerospace Equipment
T.O. 33B-1-1	Nondestructive Inspection Methods
T.O. 1-1-1	Cleaning of Aerospace Equipment

T.O. 1-1-4	Exterior Finishes
T.O. 1-1-8	Application of Organic Coatings, Aerospace Equipment

CATALOGS

H4-1, 2	Federal Supply Code for Manufacturer's Cataloging Handbook
68000-ML-AF	Federal Supply Catalog, Management Data List

HANDBOOKS

MIL-HDBK-5	Military Standardization Handbook, Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-17	Military Standardization Handbook, Plastics for Aerospace Vehicles
MIL-HDBK-23	Military Standardization Handbook, Structural Sandwich Composites
MIL-HDBK-691	Military Standardization Handbook, Adhesives

2.0 DAMAGE ASSESSMENT

2.1 GENERAL

The detection of defects in honeycomb sandwich or metal-to-metal bonded assemblies is an important part of the maintenance program. If a defect is detected early, it may usually be repaired simply at the field base. If allowed to propagate, it may endanger the safety of the aircraft or require a more costly repair at a major repair depot.

The early detection of moisture or holes where moisture can get into honeycomb panels is especially important. The presence of moisture will cause the thin foil core to corrode. Freezing and thawing of the moisture, either on the ground or during flight, may cause bond delamination. During high speed flight, pressures developed by the moisture due to the high temperatures may destroy the panel. If there is a need to delay the repair, as a minimum precaution, any moisture should be removed and the panel sealed immediately.

Little difficulty will be encountered in evaluating external damage. The blind construction of sandwich, however, makes it more difficult to detect damage that is internal. There are nondestructive inspection methods capable of detecting much of this damage. These methods range from the simple coin-tapping method to the more definitive ultrasonic and X-ray techniques. Selection of the best inspection method will depend on several factors: accessibility, type and size of defect sought, permissible inspection time, operator capability, and equipment availability. The amount of damage or size of defect that can be sustained without repair and the urgency of repair will depend on the criticality of the particular aircraft component. This information may be found in the aircraft's repair manual.

A summary of the types of defects that are typically encountered and the inspection techniques that are used to detect and evaluate them is given in table 2-1. A brief description of these is given in the following paragraphs. A more detailed description of the nondestructive inspection equipment, procedures, sensitivity, etc., is given in section 10.0.

Table 2-1.—Applicable Inspection Methods for Various Types of Defects

	Inspection method					
Type of defect	Visual	Tapping	Ultrasonic	X-ray	Eddy current	Acoustic emission
External damage	o				o	
Core-to-skin delamination	o	o	o			
Metal-to-metal delamination	o	o	o			
Internal voids			o	o		
Distorted core			o	o		
Moisture				o		
Skin cracks					o	
Corrosion						o

2.2 TYPICAL DAMAGE ASSESSMENT METHODS

2.2.1 EXTERNAL DAMAGE

Aircraft structure, in general, is quite susceptible to mechanical damage due to its typically lightweight construction. This is especially true of sandwich structure which commonly uses thin gage skins or core. Operational damage such as impact from runway debris, hail impact, or other service damage is a common occurrence. Damage is also caused by contact of service and maintenance personnel and equipment.

In most cases, mechanically caused damage is evident from visual inspection. It may be desirable, however, to more closely define the damage extent in order to determine the repair procedure in conformance with the repair manual limitations. Accurate damage assessment is necessary to determine if the structural properties of the part can practically be restored and if it is more economical to rebuild rather than replace.

Scratches

The detection and repair of scratches is important for several reasons. Scratches seriously degrade the metal's resistance to fatigue failure. Scratches that penetrate the protective coating leave the skin unprotected from corrosion.

The length and depth of the scratch and the proximity of multiple scratches should be noted. The depth can be determined with a depth gage. Whether the scratch has penetrated the cladding can be determined by applying caustic soda (sec. 6.2) to the area. If the clad has been penetrated, the base metal will turn black in contrast to the unaffected cladding. The caustic solution must subsequently be removed by thorough rinsing.

Criteria concerning scratch repair may be found in the –3 T.O. manuals. Repair procedures for small scratches are described in section 6.2. More extensive repair procedures are covered in section 7.0.

Dents

The occurrence of dents results in a general weakening of the structure. Dents in critical areas can result in premature structural failure.

The existence of dents can be noted visually (fig. 2-1). The diameter and depth should be measured. The depth can be determined with a depth gage.

If a brittle adhesive was used in construction or if the skin is quite thick, the area around the dent may be delaminated or otherwise damaged. This may be checked by tapping or, more accurately, with ultrasonic equipment. Deep dents may be checked for cracks using an eddy current meter. If a crack exists, the presence of moisture can be checked using X-ray techniques.

Criteria concerning dent repair may be found in the particular aircraft repair manuals. Repair procedures for minor dents are described in section 6.3. More extensive repair procedures are described in section 7.0.

Figure 2-1.—Dents in Surface of C-141 Wing Trailing-Edge Panel

Edge Crushing

Edge crushing (such as that shown for a weapon's bay door in fig. 2-2) can be detected visually. Similar to dents, the damage may extend beyond the obviously crushed area. A more precise definition of the damage extent may be determined by tapping or ultrasonics. Specific criteria for repair of edge crushing may be found in the aircraft repair manuals.

Quite often, this type of damage breaks the edge seal. The panel should be checked for water ingestion. This can be done using X-ray methods.

The repair procedures for crushing damage are covered in subsequent sections. Repair of minor damage is covered in sections 6.7 and 6.8. Large repair is covered in section 7.0.

Punctures and Gouges

Punctures and gouges such as that sustained by the C-141 auxiliary power unit (APU) access panel shown in figure 2-3 may be detected visually. The presence of moisture surrounding the penetration area should be checked by X-ray.

Repair procedures for relatively small damage of this type are covered in sections 6.4, 6.5, and 6.6. Procedures for larger damage repair are covered in section 7.0.

Skin Cracks

Cracks commonly emanate from fastener holes at panel edges or at fitting attachment points. They also may parallel the edge of panels that flex from sonic fatigue. The larger cracks can be detected visually either unaided or using optical magnification. Smaller cracks can be detected using an eddy current meter. If cracks are detected, the presence of moisture should also be checked. This can best be done using X-ray methods.

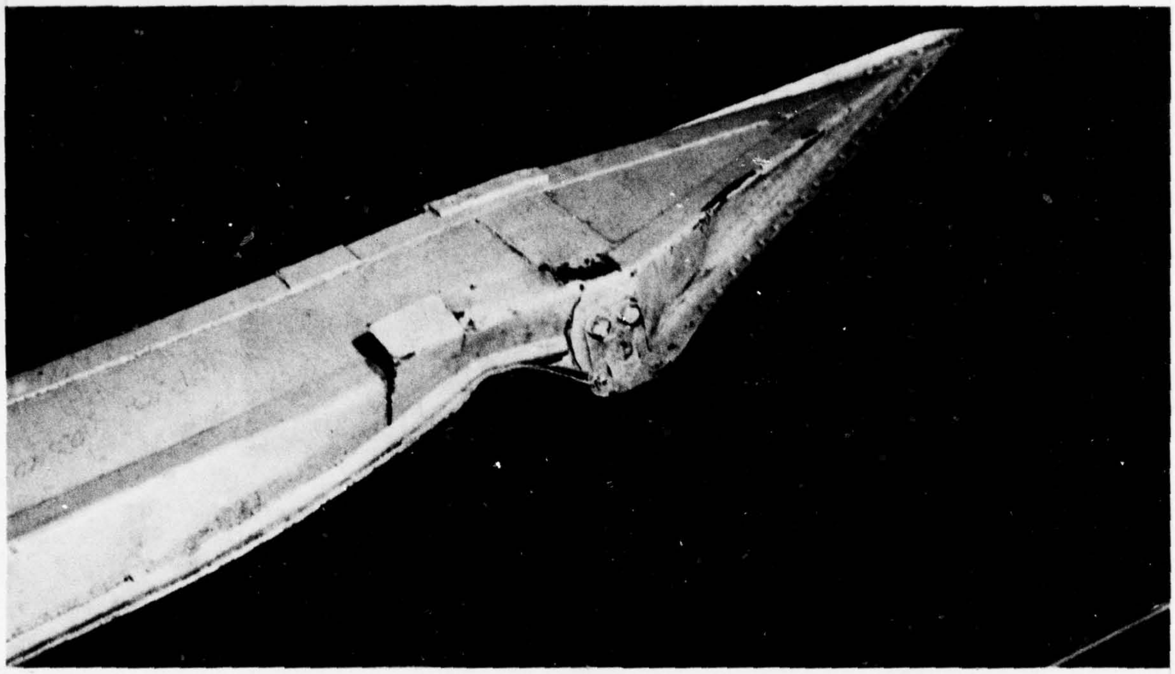


Figure 2-2.—F-111 Damaged Weapons'—Bay Lower Door

Criteria for repair of skin cracks are found in the aircraft repair manual. Procedures for the repair of small cracks are included in section 6.4. Procedures for larger damage are covered in section 7.0.

CAUTION: DO NOT Use Dye Penetrant for Crack Detection as This Will Permanently Contaminate Surfaces for Bonding.

2.2.2 INTERNAL DAMAGE

Internal damage is quite typically in the form of delaminations, crushed core, or corrosion due to ingested moisture. Nondestructive inspection (NDI) techniques are effective in detecting these types of damages.

Delaminations

Delaminations at the edge of a part such as that shown in figure 2-4 may be apparent visually or detected by tapping or ultrasonics. Internal delaminations may often be detected by viewing the panel at a low angle to the surface. Tapping is a convenient and effective method for locating the larger voids where the faces are thin. Tapping becomes less useful where the delamination is small or under thicker faces or multiple doublers or near fittings. For these cases, ultrasonic techniques

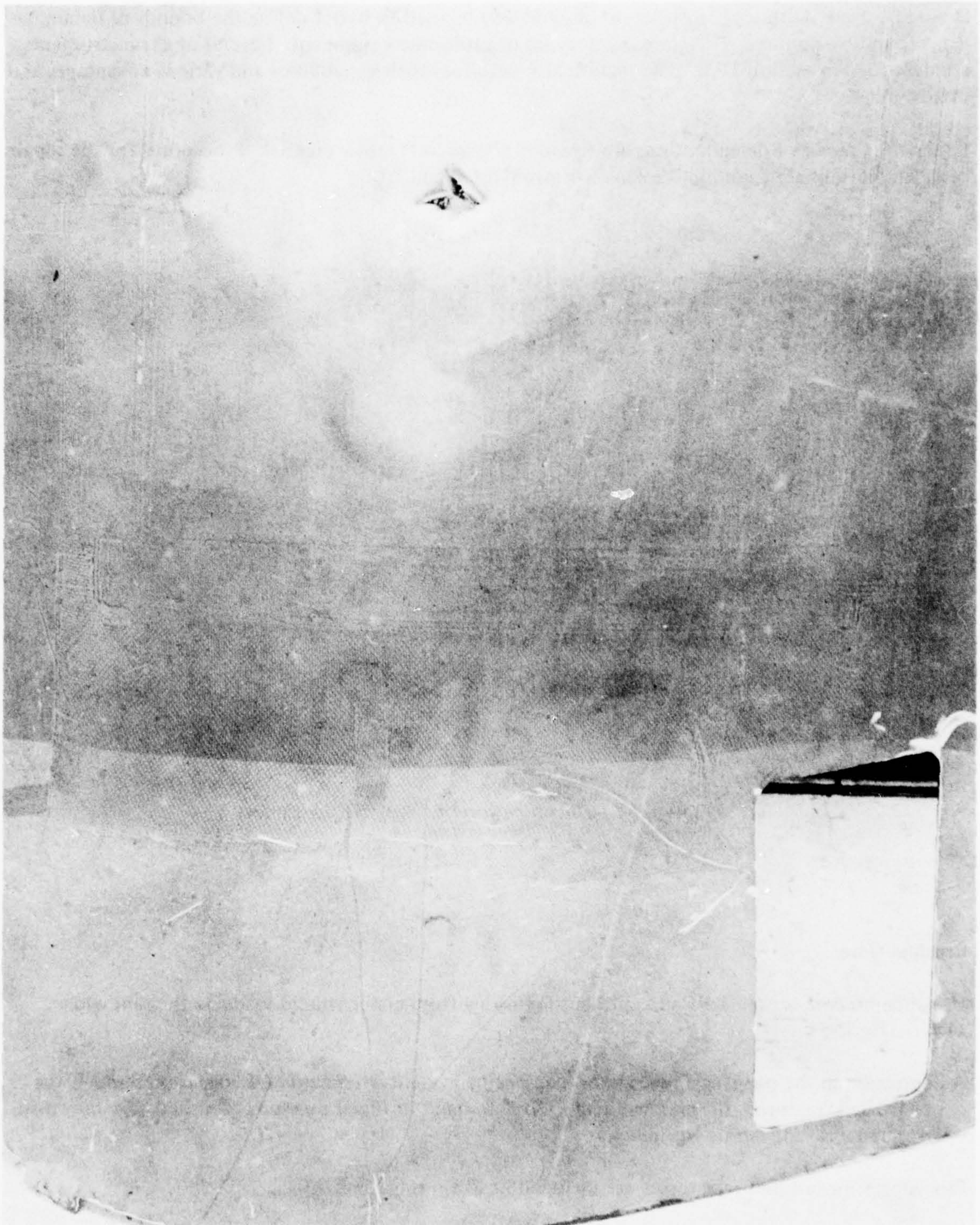


Figure 2-3.—Puncture in Honeycomb C-141 APU Access Panel

should be used. Ultrasonic instruments should also be used to better define the bounds of delaminations found by tapping. There are many types of ultrasonic equipment. Several of the instruments are described in section 10.0. The section also describes their capabilities and various advantages and disadvantages.

Criteria for repair of delaminations are found in the aircraft repair manual. Procedures for the repair of delaminations are found in sections 6.4 through 6.8 and 7.0.

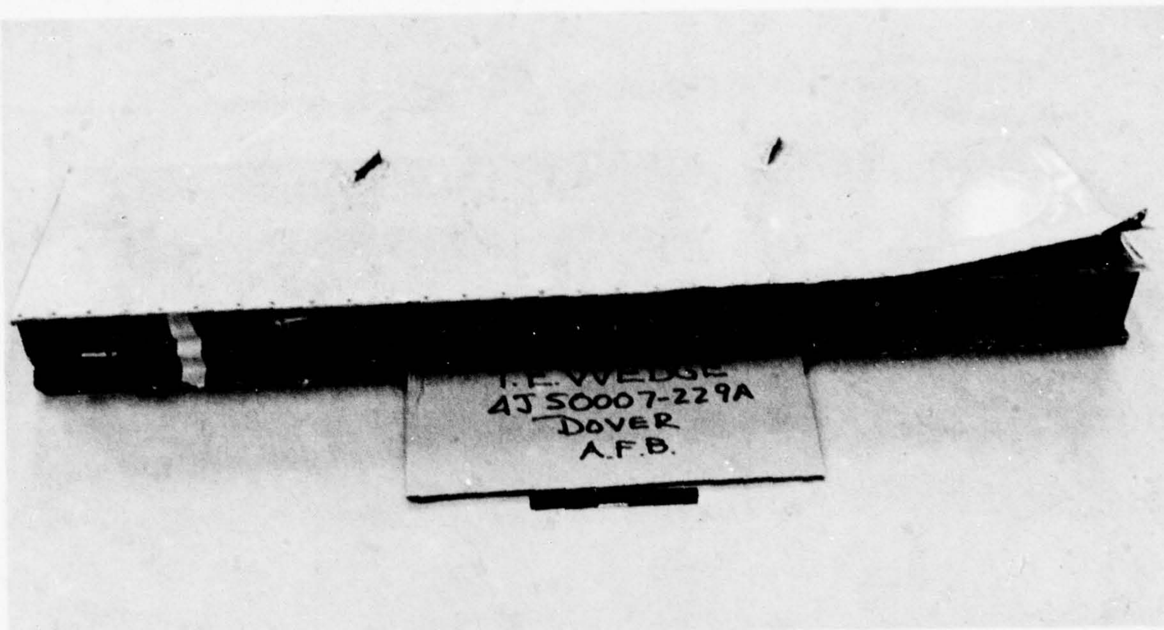


Figure 2-4.—Delamination of Trailing-Edge Panel

Crushed Core

Honeycomb core is especially susceptible to crushing from concentrated loads on the sandwich surface (fig. 2-5).

A depression in the panel surface may or may not be evident where crushed core is present. If the core has been fractured, the area will feel spongy to hand or finger pressure. Crushed core may also be detected with ultrasonic equipment or X-ray.

Procedures for crushed core repair are included in sections 6.5 and 7.0.

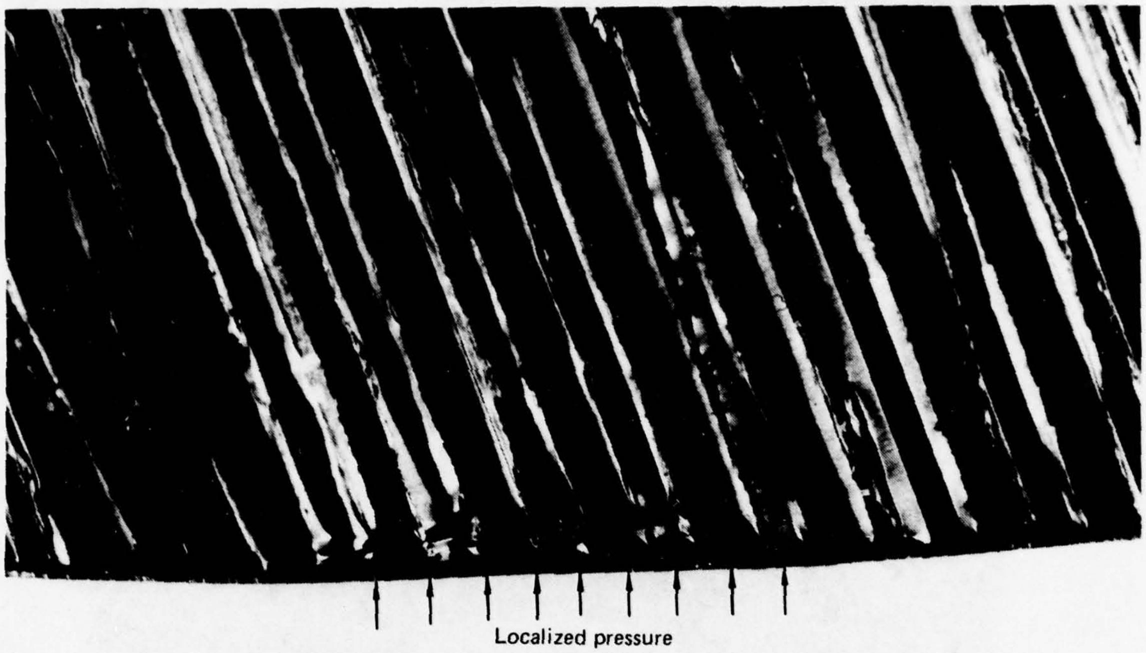


Figure 2-5.—Localized Crushed Core

Moisture

Moisture in honeycomb sandwich is a common occurrence. Moist air may enter the panel on the ground or during flight. At higher altitudes where the air is colder, the moisture condenses and is trapped in the honeycomb cells. In some cases the weight of the water may be quite large and actually impede the operation of a control surface.

In addition to the weight problems and high temperature aspects mentioned previously, the moisture works to destroy the panel interior (fig. 2-6). The core foil is very thin, and even comparatively light corrosion may significantly reduce its strength. The moisture may also destroy the bond to the core or faces or may cause corrosion to occur on the interior of the sandwich skin.

Inspection for water usually involves X-ray examination. This may be done with portable equipment or by moving the part into the laboratory. X-ray examination is usually not done unless the presence of moisture is suspected. Many of the panels examined may be a particular part from a specific aircraft model that is known to have a chronic moisture problem.

The presence of moisture in panels may be suspected from exterior examination. Quite commonly, water will enter a panel after the surface has been punctured or gouged or the edge seal has been broken by a bump. Initially a major repair might have been prevented had a piece of tape been placed over the hole to prevent moisture entry until the panel could be repaired.

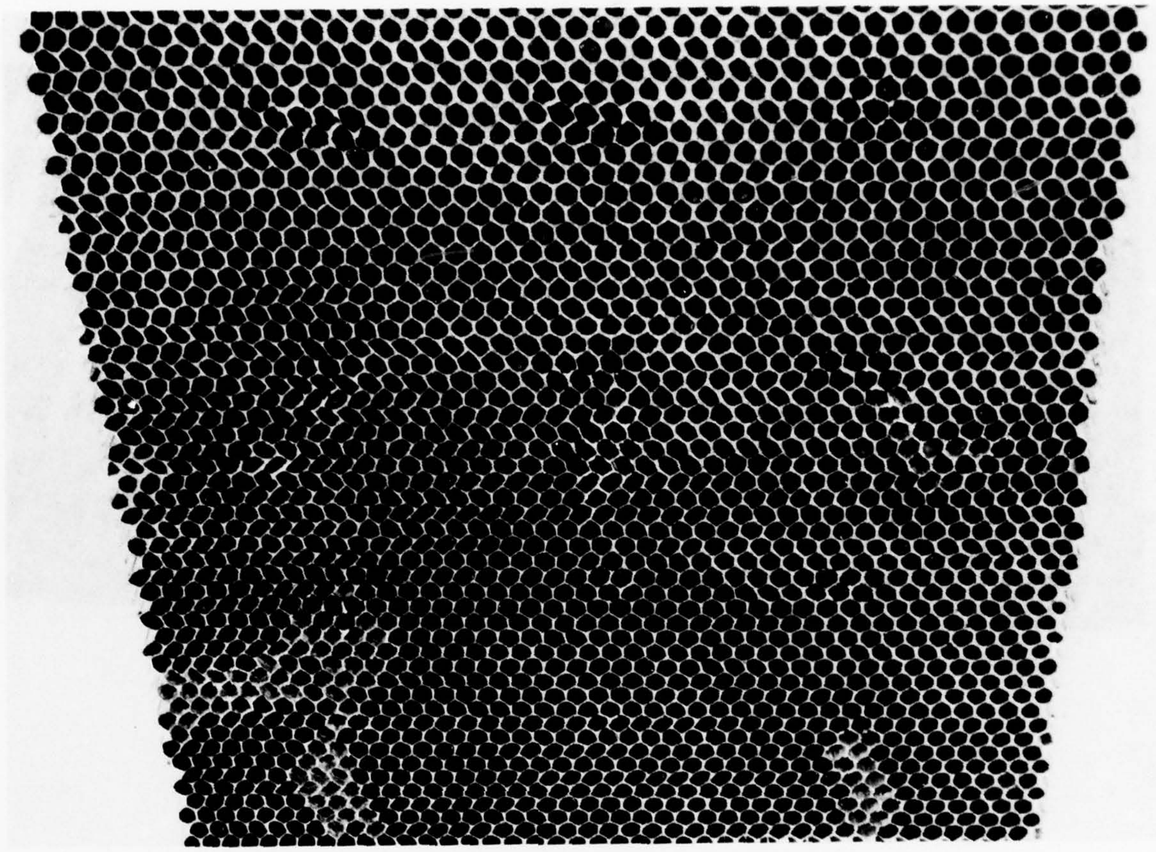


Figure 2-6.—Corrosion in Honeycomb Core

The presence of moisture can be suspected where delamination occurs near a panel edge. The condition of edge seals should be examined. Moisture entry at loose fasteners is a common occurrence. Moisture may also enter through a porous edge bond line.

In some cases the moisture remains absorbed in the adhesive layer rather than condensing in the honeycomb cells. If this causes delamination, the damage may be detected by tapping or ultrasonics. Corrosion on the underside of the aluminum skin has been detected most successfully by the use of acoustical emission techniques.

Generally, where moisture is detected, the panel should be opened up sufficiently to determine the extent of corrosion.

Moisture removal techniques are described in section 7.3.5.

Corrosion

After an adhesive failure/disbond begins, one of the major structural degrading factors is corrosion. Corrosion is the breakdown of a metal due to electrochemical action. Corrosion products can destroy adhesive bonds by adding chemicals and creating a wedging action to accelerate the failure.

Inspection for corrosion on aircraft is usually an examination for aluminum corrosion products. These corrosion residues are usually white and rather powdery. Corroded honeycomb will have a dull, dirty appearance in contrast to the clean, often shiny, and uniform appearance of sound core. T.O. 1-1-2 describes most of the common forms of corrosion. On structural surfaces corrosion may be an exfoliation or general surface attack. If corrosion damage has occurred, it is essential that all of the corrosion products are removed. Corrosion in an aircraft is like a cancer. If some is still present after treatment, the corrosion will grow and cause more damage. Corrosion treatment is defined in the aircraft -23 manuals and T.O. 1-1-2.

3.0 REPAIR METHOD SELECTION

A guide to the appropriate section for small repairs to honeycomb sandwich or laminated metal structure is found in table 3-1. The use of these methods is subject to the limitations stipulated in the specific aircraft repair manuals. Extension of these to large repairs must be authorized by the responsible engineering agency. Procedures for larger repairs and rebuilding are covered in section 7.0.

In general, emphasis is placed on utilizing methods that will minimize subsequent problems with moisture and corrosion. The approach is to utilize well-prepared bonding surfaces, impermeable heat- and pressure-cured adhesives, and adequately sealed panel or patch edges. The latter involves the use of a minimum width peripheral bondline plus sealant.

The patch-type approach is generally most expedient and economical where it can be used. For larger repairs or highly stressed areas, however, it may be necessary to replace entire detail parts. Replacement of the damaged details allows the component to be restored to its original strength and surface contour.

Rebuilding or replacement of detail parts (e.g., skins) may be in order when high service temperatures are encountered. This is because of the lower strength of the adhesives at the higher temperatures and hence their limitations in transferring structural loads. If a patch repair is used in these areas, it may be necessary to resort to mechanical fasteners, possibly in combination with bonded doublers. Allowable design strengths for mechanical fasteners are given in MIL-HDBK-5. The total thickness of the skin plus the bonded doubler may be used for determining the bearing strength.

Table 3-1.—Guide to Repair Method Selection

Item	Type of damage	Type of structure	Applicable repair section
1	Scratches		
	Light scratches in aluminum	All	6.2.1
	Light scratches in titanium	All	6.2.1
	Deep scratches	All	6.2.2
2	Dents	Honeycomb sandwich	6.3
		Metal laminates	6.9
3	Delaminations	Honeycomb sandwich	6.4
		Metal laminates	6.9
4	Cracks	Honeycomb sandwich midpanel	6.4
		Honeycomb sandwich edge close-out	6.7
		Metal laminates	6.9
5	Holes		
	Through one skin	Honeycomb sandwich midpanel	6.4, 6.5
		Metal laminates	6.9
	Through both skins	Honeycomb sandwich midpanel	6.6
		Metal laminates	6.9.2, 6.9.3
	Other	Honeycomb sandwich	6.7
6	Edge crushing	Honeycomb panel zee edge close-out	6.7
		Honeycomb panel trailing edge	6.8
7	Crushed core	Honeycomb sandwich	6.5
8	Presence of moisture	Honeycomb sandwich	7.0
9	Corrosion	All	7.0

4.0 MATERIALS AND PROCESSING

4.1 MATERIAL SELECTION

This section contains information pertinent to the selection of materials used when making repairs on or off the aircraft. The materials are classified into general use classifications as follows:

- Metal-to-metal adhesives
- Metal-to-core adhesives
- Aerodynamic smoothers
- Injectable honeycomb potting compounds
- Splice adhesives: core-to-core, core-to-fitting
- Core filler/potting compounds
- Sealants/aerodynamic smoothers
- Honeycomb cores
- Glass fiber resin

The materials listed in tables 4-1, 4-2 and 4-4 are intended as guides in making repairs. No restrictions are placed on the use of equally acceptable materials or equivalents except that their use must be approved by the applicable authority, e.g., system manager or the aircraft structural engineer. THE LISTING OF ANY TRADE NAME OR COMMERCIAL PRODUCT DOES NOT CONSTITUTE AN ENDORSEMENT OF THE PRODUCT BY ANY GOVERNMENT AGENCY.

A brief description of the repair materials is provided in the following paragraphs.

4.1.1 ADHESIVES, METAL-TO-METAL AND METAL-TO-CORE

Several types of adhesives are used in bonded repairs. Adhesives are provided in various forms, as regular or foam tape, or in liquid form (filled and unfilled) to facilitate various repairs. The adhesives included in this handbook have been especially selected for their strength, toughness, environmental durability, and processing characteristics.

Adhesives are available for various service temperatures. On the basis of the cure temperature and upper service temperature limits, the adhesive-bonding repair materials are further classified into the following types.

1. Room temperature (RT) cure materials for 140 to 180^{o} F service
2. Elevated temperature (up to 250^{o} F) cure materials for 180^{o} F service

3. Room temperature cure materials for 350° F service

4. Elevated temperature (up to 350° F) cure materials for 350° F service

5. Elevated temperature (up to 350° F) cure materials for 400° F service

Material selection criteria are based on various parameters influencing the repair. Within each type of material, the upper service temperature and cure temperature, together with the strength properties requirements, are considered primary factors affecting material selection. The following items should be noted and used as guides:

1. Regarding the maximum service temperature:

   - Requirements for the aircraft are defined in the applicable aircraft T.O.

   - A temperature of 180° F is generally applicable to subsonic aircraft such as transports. Exceptions are the high heat areas around the engine and the auxiliary power unit (APU).

   - Temperatures of 350° F and 400° F are more generally applicable to supersonic aircraft such as fighters and attack aircraft.

2. When possible, equivalent elevated temperature cure instructions are included for the RT cure materials. These are for use where the repair schedule does not allow the longer RT cure period.

3. When possible, optional lower curing temperatures are provided for the elevated temperature curing systems. The use of the lower temperature cure may be desirable because:

   - If the repair is in a local area, it may be difficult to get the area up to temperature because the heat is conducted away by the surrounding structure. This is the case when the repair is near a heavy metal fitting or on heavy metal structure. In these cases, an adhesive that allows a low minimum-heat-up rate may be required.

   - An adhesive with a cure temperature lower than that of the original adhesive may be required if the part is repaired locally and not completely supported in a bonding tool. This is because of softening of the surrounding adhesive. Generally, a cure temperature 50° F lower than that of the original cure temperature is acceptable.

4. Elevated temperature cure adhesives are generally preferred to room temperature curing systems. They are typically stronger, tougher, and have better environmental resistance.

5. In general, it is recommended that the higher service temperature adhesives, i.e., 350° or 400° F, not be used when the 180° F service adhesives are sufficient. This is because compromises have been made to gain the higher use temperature. The higher temperature adhesives typically have lower strength and toughness (for example, lower peel strength).

Adhesive primers associated with each adhesive material are recommended for use following surface preparation. Both standard (noncorrosion-inhibiting) primers and corrosion-inhibiting primers are suitable for repair applications. Corrosion-inhibiting primers typically require spray equipment of the recirculating type. However, corrosion-inhibiting adhesive primers are preferred because of the improved bond environmental durability. Air-drying noncorrosion-type primers may be applied by nonspraying methods such as brushing or wiping-on.

For small area repairs, the use of primers is optional if the elapsed time from surface preparation to bond is held to a minimum, typically less than 8 hours. However, for large area repairs or refabrication, it is recommended that corrosion inhibiting primers always be used because of the use of manufacturing and handling operations that are more prone to contamination.

Manufacturers' mixing and handling instructions should be followed for mixing and curing adhesives. Some typical mixing and cure conditions are given in table 4-3. General preparation procedures for adhesive primers and film adhesive application are given in section 4.3.

4.1.2 ADHESIVES, CORE SPLICE

Core splice adhesive materials are used to join core-to-core segments or to accomplish core-to-extrusion or core-to-fitting bonds. Both foaming tapes and nonfoaming tapes are available as well as paste type for buttering or trowel applications. Depending on the service environment, room temperature cure paste has the advantage of being easier to apply and can be cured prior to final assembly. On the other hand, in most cases, heat cure splice bonds may be cured at the time of skin bonding. The choice of which type splice adhesive to use will depend on the configuration of the part, service environment, and availability of materials. When a core splice is not available, multiple layers of film adhesive may be substituted.

4.1.3 AERODYNAMIC SMOOTHERS

Aerodynamic smoothers are used on the external surfaces of the aircraft in fastener head grooves, in external sealing grooves, in gaps at skin panel splices, or to fair the edge of repair patches.

4.1.4 POTTING COMPOUNDS, CORE FILLER

These materials are used to fill dents and core damage. These are usually resin adhesives containing an inert filler. They typically can be cured at room temperature or quick cured at moderate temperatures. Application is usually by trowel or spatula.

4.1.5 POTTING COMPOUNDS, INJECTABLE HONEYCOMB

These materials are similar to the other potting compounds except they have a lower viscosity for injection applications.

4.1.6 SEALANTS/AERODYNAMIC SMOOTHERS

Sealants used for repairs will be dependent on the service temperature, aerodynamic smoothness requirements, and fuel/fluid resistance criteria. Both corrosion-inhibiting and noncorrosion-inhibiting types are available for general applications and for service temperatures to 350° F. (See table 4-1.)

Table 4-1.—Preferred Repair Materials List

Material	Type	Maximum service temp	Cure temp	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Adhesives (metal-to-metal and metal-to-core)	I	140° F	RT	EA 9309	The Dexter Corp.		Two-component epoxy paste
				EA 9320	The Dexter Corp.		Two-component epoxy paste
				AS 401-1	Adhesive Engineering		Two-component epoxy paste
	II	180° F	200° to 250° F	AF 127-3/EC 3921[a]	3M		Supported film
				AF 126/EC 2320[a]	3M		
				FM 123-2	American Cyanamid		
				FM 73	American Cyanamid		
				EA 9628	The Dexter Corp.		Supported film
				BR 127[b]	American Cyanamid		Corrosion-inhibiting primer
				EC 3950[b]	3M		Corrosion-inhibiting primer
	III	350° F	RT	EA 934	The Dexter Corp.		Two-component adhesive
	IV	350° F	270° to 350° F	AF 130	3M		Supported film adhesive; used with or without primer

[a]The number after the slash indicates the non corrosion-inhibiting primer system normally used with that adhesive.

[b]A corrosion-inhibiting primer, compatible for use with Type II adhesives.

Table 4-1.—(Continued)

Material	Type	Maximum service temp	Cure temp	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
				Reliabond 398	Reliable Mfg.		Supported film adhesive; used with or without primer
		350° F	350° F	FM 300	American Cyanamid		Supported film adhesive
				AF 147	3M		Supported film adhesive
	V	400° F	350° F	FM 400 (BR400 CIAP primer)	American Cyanamid		Supported film adhesive
Adhesives (core splice)	I	180° F	RT	EC 1751 A/B	3M		Two-part paste
	II	180° F	250° F	AF 3006	3M		Foam tape
				AF 3015 class 250	3M		
				FM 40 class 250	American Cyanamid		Foam tape
				EC 3439	3M		One-component paste
	IV	350° F	350° F	Plastilock 654	B.F. Goodrich		Foam tape
				AF 3015 class 350	3M		
				FM 40 class 350	American Cyanamid		
	V	400° F	350° F	Thermofoam 3009	Adhesive Engineering		Foam tape

Table 4-1.—(Continued)

Material	Type	Maximum service temp	Cure temp	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Aerodynamic smoother[c]	I	180^{o} F	RT	EC 2216 A/B	3M		Two-part epoxy paste
				MIL-S-38228 Pro Seal 895	Coast Pro Seal		
				MIL-S-81733 PR1436G	Products Research		
	III	350^{o} F	RT	Metalset A-4	Smooth On Co.		Two-part epoxy paste
Honeycomb core, aluminum							
Density (lb/ft^3) Cell size (in.)							
3.1 1/8	III	350^{o} F		1/8-5052-0.0007N	Hexcel Corp.		Also available in other alloys (5056, 2024) and other densities and cell sizes.
				3-1-1/8-07N(5052)	American Cyanamid		
4.5 1/8	III	350^{o} F		1/8-5052-0.001N	Hexcel Corp.		
				4.5-1/8-10N(5052)	American Cyanamid		
8.1 1/8	III	350^{o} F		1/8-5052-0.002N	Hexcel Corp.		
				8.1-1/8-20N(5052)	American Cyanamid		

[c]Not to be used for structural bonding

Table 4-1.–(Continued)

Material	Type	Maximum service temp	Cure temp	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Honeycomb core, fiberglass							
Density (lb/ft^3) Cell size (in.)							
4.0 3/16	III	350° F		HRP3/16GF11-4.0	Hexcel Corp.		Glass-fabric resin-reinforced core also available in other densities and cell sizes.
				HTP3/16-4.0	Orbitex Inc.		
7.2 3/16	III	350° F		HRP3/16-7.2	Hexcel Corp.		
				HTP3/16-7.2	Orbitex Inx.		
Honeycomb potting compound, injectable	I	180° F	RT	AS 401-1	Adhesive Engineering		Two-part epoxy type compound
	III	350° F	RT	Aerobond 2199	Adhesive Engineering		Two-part epoxy type compound
	IV	350° F	350° F	Epocast 1843 A/B type 4 grade A	Furane Plastics		Two-part syntatic foam
Honeycomb potting compound, trowelable	I	180° F	RT	AS 401-1	Adhesive Engineering		Two-part filled epoxy paste
	III	350° F	RT	EA 934 A/B	The Dexter Corp.		Two-part filled epoxy paste
	IV	350° F	350° F	Epocast 1843 A/B type 4 grade B	Furane Plastics		Two-part syntactic foam

Table 4-1.—(Concluded)

Material	Type	Maximum service temp	Cure temp	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Resin, glass fiber	I	180° F	RT	Epon 828/812	Shell Chemical		For fiberglass layup patching
				Versamid 115/125	General Mills		
			RT or 160° F	Epocast HT1835/ 9816	Furane Plastics		For fiberglass layup patching
			RT or 160° F	Epocast HT1835/ 946	Furane Plastics		
	III	350° F	RT	Epocast 38/9231	Furane Plastics		Two-part epoxy resin system for wet layup patching
Sealants[c]	I	180° F	RT	MIL-S-81733 PR 1432 G	Products Research		Corrosion-inhibiting chromate type
				PR 1436 G	Products Research		
				PR 1422 G	Products Research		
				MIL-S-8802 Pro Seal 890	Coast Pro Seal		For general applications where corrosion is not a problem
	III	350° F	RT	MIL-S-83430 Pro Seal 899	Coast Pro Seal		For higher temperature applications
				PRC 1751	Products Research		

[c]Not to be used for structural bonding

4.1.7 HONEYCOMB CORES

Both aluminum and glass-reinforced honeycomb cores are used in bonded repairs. Aluminum core shall be a nonperforated corrosion-resistant type and either 5052 or 5056 alloy. Wide ranges in density and cell size are available. A few typical callouts are given in table 4-1.

4.1.8 GLASS FIBER RESIN

Prepregs, glass fabric cloth, chopped glass fibers, and resins may be used to repair aluminum panels if approved by the responsible engineering agency.

4.2 REPAIR MATERIALS

This section is divided into two parts. Section 4.2.1 comprises the materials incorporated in a repair, while section 4.2.2 is for miscellaneous or nonincorporated materials.

The preferred repair materials list is given in table 4-1. This lists the material type, category, manufacturer's number, manufacturer's name, federal stock number where available, storage life, and general remarks.

A list of alternate materials is also given (table 4-2) for each type under the applicable categories.

Table 4-3 in section 4.2.1 gives the mixing instructions, cure conditions, or handling information, and work life of some repair materials.

Cleaners and surface preparation and corrosion protection materials are found in table 4-4.

4.2.1 MATERIALS INCORPORATED IN THE REPAIR

Preferred Repair Materials

Table 4-1 provides a listing of candidate materials for each type of repair material in the various categories depending on service temperature and cure temperature. This is a preferred material list. If the listed materials are not available under the appropriate type and category, proceed to table 4-2 for the alternate materials list. If the materials listed there are also not available, use a substitute or equivalent with the approval of the appropriate authority. For adhesive materials, specifications MMM-A-132 and MIL-A-25463 provide source information and minimum strength requirements.

Alternate Materials

Table 4-2 gives the alternate materials in each category for each general type. The intent of this list is to provide alternate callouts for materials if the listed materials in table 4-1 are not available.

This list has been compiled from various technical orders (T.O.'s) and repair documents applicable to the services. When the desired material to be used for a repair is neither listed in table 4-1 nor 4-2, obtain approval from an applicable source for use of equivalent materials.

Table 4-2.—Alternate Repair Materials List

Material	Type	Maximum service temp	Cure temp	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Adhesives (metal-to-metal and metal-to-core)	I	140^{o} F	RT	EC 2054	3M		
				EC 1751/EC1752	3M		
				Tame 200PB-2	B.F. Goodrich		Use for small area metal-to-metal bond repairs
	II	180^{o} F	200^{o} to 250^{o} F	EA 9601/EA 9621	The Dexter Corp.		
				AF 11	3M		
				FM 47	American Cyanamid		
				Epon VIII/A	*Shell Chemical*		
	IV	350^{o} F	270^{o} to 350^{o} F	Aerobond 3030	Adhesive Engineering		
				Metlbond 329	Narmco		
		350^{o} F	350^{o} F	FM 61/BR227	American Cyanamid		
				FM 96/BR227	American Cyanamid		
	V	400^{o} F	350^{o} F	AF 131	3M		
				Plastilock 677	B. F. Goodrich		
				HT 424	American Cyanamid		

Table 4-2.–(Continued)

Material	Type	Maximum service temp	Cure temp	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Aerodynamic smoother[a]	I	180° F	RT	AS 401-1	Adhesive Engineering		
				EA 9309.2	The Dexter Corp.		
				Epocast 8651	Furane Plastics		
				Narmco 3135 plus glass fiber	Narmco		
				Epon 828 plus Versamid 125 plus aluminum powder	Shell Chemical General Mills		
	III	180° F	RT	EC 5123 A2/B2	3M		
Injectable honeycomb potting compound	I	180° F	RT	EA 9309.2	The Dexter Corp.		
				Narmco 3135	Narmco		
				EC 1751/EC 1752	3M		
				Epon 828/DTA	Shell Chemical		
				Epon 828/812 plus Versamid 115/125	Shell Chemical General Mills		
				Epon 828 plus Versamid 125 plus aluminum powder	Shell Chemical General Mills		
	III	350° F	RT	Epon 9300 A/B	Shell Chemical		

[a] Do not use for structural bonding

Table 4-2.–(Continued)

Material	Type	Maximum service temp	Cure temp	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Injectable honeycomb potting compound (cont)	IV	350° F	350° F	Epocast 8542/38	Furane Plastics		
				Epocast 9242/8542B	Furane Plastics		
Core splice adhesives	I	180° F	RT	Epon 828/812 plus Versamid 115/125	Shell Chemical General Mills		
				EC 1751/EC 1752	3M		
				Epon 815/T plus microballoons	Shell Chemical		
	II	180° F	200° to 250° F	FM 37	American Cyanamid		
				Reliabond 370B	Reliable Mfg.		
	V	350° F	350° F	HT 424 Foam	American Cyanamid		
				Plastilock 653EX	B. F. Goodrich		
Core filler	I	180° F	RT	EC 1751 A/B	3M		
				Epon 828/DTA plus aluminum powder	Shell Chemical		
				Corfil 615	American Cyanamid		
				Epocast 8651	Furane Plastics		
				Epon 828 plus Versamid 125 plus aluminum powder	Shell Chemical General Mills		

Table 4-2.–(Concluded)

Material	Type	Maximum service temp	Cure temp	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Core filler (cont)				EC 2216	3M		
	III	350° F	RT	Aerobond 2219 A/B plus glass fiber	Adhesive Engineering		
Glass fiber resin	I	180° F	RT	Narmco 3135	Narmco		
				Narmco 7125/3147	Narmco		
				Epon 828/DTA	Shell Chemical		

Table 4-3.—Repair Materials Processing Data

Material	Manufacturer's designation	Storage life	Mixing proportions	Working life	Curing conditions	Remarks
Adhesives (metal-to-metal and metal-to-core)	EA 9320	12 months at RT	100 parts A 25 parts B	30 min at 65° to 80° F	7 days at RT or 2 hr at 160° F	Mix only the amount of material that can be used within the working life
	EA 9309	12 months at RT	100 parts A 22 parts B	60 min at 65° to 80° F	1 hr at 150° F 12 hr handling 5 days RT cure	Mix only the amount of material that can be used within the working life
	AF 127-3 AF 126 FM 73 EA 9628	6 months at 0° F for adhesives and 40° F for primers	Film form	7 to 10 days open time in controlled room conditions	60 to 90 min at 225° to 250° F or 120 min at 200° F	Cure the assembled part as soon as practical or leave under vacuum
	EA 934 A/B	4 months at RT	100 parts A 33 parts B	1 hr at 65° to 80° F	5 hr at RT plus 1 hr at 160° F, or 5 days at RT	Mix only the amount that can be used within working life
	AF 130	Six months at 0° F for adhesives and 40° F for primers	Film form	1 to 7 days open time in controlled room conditions	60 min at 350° F or 120 min at 270° F	Cure the assembled parts as soon as practical or leave under vacuum
	Reliabond 398	Six months at 0° F for adhesives and 40° F for primers	Film form		60 min at 350° F	Cure the assembled parts as soon as practical or leave under vacuum
	FM 400	Six months at 0° F for adhesives and 40° F for primers	Film form	1 to 7 days open time (protected) in controlled room conditions	60 min at 350°F	Cure the assembled parts as soon as practical or leave under vacuum

Table 4-3.—(Continued)

Material	Manufacturer's designation	Storage life	Mixing proportions	Working life	Curing conditions	Remarks
Aerodynamic smoother	EC 2216 A/B	12 months at RT	140 parts A 100 parts B	2 hr at 65° to 80° F	24 hrs at RT or 2 hr at 160° F	Use for smoothing application only
	Metalset A4	12 months at RT	100 parts A 100 parts B	1/2 hr at 65° to 80° F	24 hr at RT or 1/2 hr at 150° F	Mix only the amount that can be used within the working life
Injectable honeycomb potting compound	AS 401-1	6 months at RT	100 parts A 15 parts B	2 hr at 65° to 80° F	12 hr at RT or 1/2 hr at 160° F	Mix only the amount that can be used within the working life
	Aerobond 2199	6 months at RT	100 parts A 40 parts B	Open time is 1 to 7 days	2 hr at 270° F	Cure assembled parts as soon as practical
	Epocast 1843, type 4, grade A	12 months at RT	100 parts A 18 parts B	6 hr at 65° to 80° F	2 hr at 200° F plus 1 hr at 350° F	Grade A is pourable
Core splice adhesive	EC 1751 A/B	12 months at RT	100 parts A 50 parts B	45 min at RT	48 hr at RT or 1 hr at 150° F	Use for joining core-to-core pieces to form large sections or to splice to original core
	Class [a]250: AF 3006	6 months at 0° F	Tape form	Open until heat cure	200° to 250° F for 60 min	
	Class [a]250: AF 3015	6 months at 0° F	Tape form	Open until heat cure		
	Class [a]250: Thermofoam 3050	6 months at 0° F	Tape form	Open until heat cure		
	Class [a]250: FM 41	6 months at 0° F	Tape form	Open until heat cure		

[a]Class 250 is a 250° F curing system

Table 4-3.–(Concluded)

Material	Manufacturer's designation	Storage life	Mixing proportions	Working life	Curing conditions	Remarks
Core splice adhesive (cont)	Plastilock 654	6 months at 0° F	Tape form	Open until heat cure	270° to 350° F for 60 min	Use for joining core-to-core pieces to form large sections or to splice to original core
	Class [b]350: AF 3015	6 months at 0° F	Tape form	Open until heat cure		
	Class [b]350: *Thermofoam* 3050	*6 months at* 0° F	Tape form	Open until heat cure		
	Class [b]350: FM 41	6 months at 0° F	Tape form	Open until heat cure		
	Thermofoam 3009	6 months at 0° F	Tape form	Open until heat cure	350° F for 60 min	
Core filler	AS 401-1	6 months at RT	100 parts A 15 parts B	2 hr at 65° to 80° F	12 hr at RT or 1/2 hr at 160° F	Use for core potting or filling
	EA 934 A/B	12 months at RT for resin; 6 months at 40° F for catalyst	100 parts A 33 parts B	1 hr at 65° to 80° F	5 days at RT or 5 hr at RT plus 1 hr at 160° F	Use for core potting or filling
	Epocast 1843, type 4, grade B	12 months at RT	100 parts A 15 parts B	3 hr at 65° to 80° F	1/2 hr at 170° F plus 1 hr at 250° F	Grade B is nonflow paste
Glass fiber resin	Epon 828/812 Versamid 115/125	12 months at RT	Equal parts of each component	2 hr at 65° to 80° F	24 hr at RT or 1 hr at 180° F	Use for fiberglass patch repair
	Epocast 38 Hardener 9231	12 months at RT	100 parts 20 parts	10 to 12 hr at RT	300° F for 1 hr	Use for fiberglass patch repair
	Epocast HT1835 Hardener 981b	12 months at RT	100 parts 10 parts	1 hr at RT	12 hr at RT or 2.5 hr at 160° F	
	Epocast HT1835 Hardener 946	12 months at RT	100 parts 15 parts	1 hr at RT	5 hr at RT or 2.5 hr at 160° F	

Class 350 is a 350° F curing system

Follow the manufacturer's recommended mixing ratios for those materials that require on-site mixing prior to use. Addition of filler materials such as aluminum powder or microballoons to improve application and handling are optional.

Mixing and Curing Requirements

This section gives the mixing information, cure time, and working life of mixed materials. The working life listed in table 4-3 represents typical time for small batch conditions. Mix only the amount of material that can be used up within the specified time. In general the information given represents typical conditions. Specific applications may require deviation from the given conditions. In those situations, the manufacturers' recommended mixing instructions, heat-up rate, cure time, and pressure requirements should be followed.

Film adhesives are available in varied weights ranging from 0.03 to 0.20 lb/ft^2 or thicknesses from 5 mils to 20 mils. Typically, the thicker films (10 to 20 mils) are used for sandwich panels in skin-to-core bond to improve fillet formation and bond strength. The thinner films (5 to 7 mils) are used for metal-to-metal bonds such as doublers, closeouts, or fittings. For repair in general, a 10 mil adhesive film is recommended for metal-to-metal applications and a 15 mil thick film is recommended for metal-to-core usage.

Cleaners and Corrosion Protection Materials

This section lists cleaners and components to prepare corrosion protection solutions (table 4-4):

Observe the following precautions when handling or mixing the cleaners or solutions.

- **Avoid skin contact**
- **Wear safety goggles**
- **Wear rubber gloves**
- **Mix and use in ventilated areas**

Directions on the use of specific materials are contained in the repair procedures sections, 6.0 and 7.0, surface preparation section 5.0, and section 4.3.4 for application of protective chromate conversion coating.

Where MEK is called out as a solvent for cleaning, Freon or other equivalent solvents may be used if MEK is prohibited. CHECK LOCAL SAFETY REQUIREMENTS.

Exercise care when using solvents, alkaline cleaners, or acid on the aircraft structures, as these materials can damage insulation materials, cause subsequent corrosion, etc.

Additional information on solvents can be found in T.O. 42A1-1-3.

Table 4-4.—Cleaners and Corrosion Protection Materials

Material	Manufacturer's no. or specification no.	Manufacturer	Mixing instructions	General remarks
Alkaline cleaner	MIL-C-25769	Any source		Cleaning scratches penetrated clad surfaces
Chromate conversion coating	MIL-C-5541 MIL-C-81706 Alodine 1200	Am Chem Products Amber, Pa	3 oz of Alodine 1200 *powder to each gallon* of water	For corrosion protection
	Iridite 1200 Turco 4178 Chromicoat L25			
Chromium trioxide	0-C-303	Any source	Mix 50 g of chromium triozide to 1 liter of water	Neutralize caustic soda solution
Cleaning solvent	MIL-C-38736	Any source		
Distilled water	*Any source*			Solution make-up
Gelled phosphoric acid	PR 50 (10% to 12% by *weight)*	Products Research *Glendale, Calif.*	Use as received	Anodize aluminum
Hydrofluoric acid	2% aqueous solution	Any *source*	2 parts HF by volume to 98 parts water	Cleaning aluminum
Paste cleaner	PasaJell 105	Products Research Glendale, Calif.	Use as received	Aluminum surface preparation
Paste cleaner	PasaJell 107	Products Research Glendale, Calif.	Use as received	Titanium surface preparation

Table 4-4.—(Concluded)

Material	Manufacturer's no. or specification no.	Manufacturer	Mixing instructions	General remarks
Phosphoric acid	Fed spec 0-0-670, 75%	Any source	Make 10% to 12% solution concentration by weight; may be thickened by adding Cab-O-Sil to form paste (e.g., add 1/2 gallon Cab-O-Sil to 200 ml acid)	Anodize aluminum
Sodium hydroxide solution (caustic soda)		Any source	Mix 1 oz of 50% sodium hydroxide solution to 4oz of water	

4.2.2 MATERIALS NOT INCORPORATED IN THE REPAIR

The materials listed in table 4-5 are intended to serve as guides and typical source callouts. Approved equivalents may be substituted as alternates to those listed. The list is merely for use as a convenient reference for sources of supply. It is not meant to give favorable endorsement to the particular suppliers listed.

4.3 MATERIALS PROCESSING

This section presents information concerning primer preparation and application, film adhesive preparation and application, and paste or liquid/paste adhesive preparation and application. Only guide information is provided in each of the areas. Specific information and data should be obtained from the applicable specifications, manufacturer's instructions, and related documents.

4.3.1 PREPARATION AND APPLICATION OF PRIMER

Depending on the availability of spray equipment and the size of the repair part, corrosion-inhibiting or noncorrosion-inhibiting primers may be applied either by spraying or manual brush or wipe-on applications. The use of primers is recommended to improve durability and prevent contamination during handling and assembly.

It is recommended that corrosion-inhibiting adhesive primers (CIAP) be used for the RT- and 250° F-curing adhesive systems if equipment and skilled personnel are available. CIAP surfaces are generally compatible with a wide variety of adhesive systems. Improved bond durability is obtained with CIAP primer compared to standard non-CIAP primer. Another advantage of using CIAP primer is that cured CIAP-primed skins or details may be stored for one to three years when protected from contamination or exposure to sunlight (see section 1.2.5). IF IT IS NECESSARY TO REMOVE THE PRIMER AFTER APPLICATION THE NONBAKED PRIMERS CAN BE REMOVED WITH A SOLVENT. THE BAKED PRIMERS MUST BE REMOVED BY MECHANICAL ABRADING.

Nonspray Method of Primer Application

1. Condition the refrigerated primer by allowing it to come to room temperature prior to opening the container.

2. Do not use primer containing lumps or indication of gellation.

3. Agitate or stir the primer to assure a homogeneous mixture. When applying CIAP primer by a nonspray manual method (e.g., wiping), agitate prior to each application to restore suspension of solids.

4. Brush or gauze-wipe a smooth, uniform film of primer on the cleaned surfaces.

5. Allow to air dry for 60 minutes and then bake as required by manufacturer's instructions.

Table 4-5.—Miscellaneous and Nonincorporated Materials

Materials	Manufacturer's no. or specification no.	Supplier	Federal stock no.	General remarks
Protective coating (temporary)	TEC 556P, TEC 556-6625P, or TEC 755A	TEC Chemical Co. 524 Monterey Pass Rd. Monterey Park, CA. 91754		Provide temporary protection on panel skins or details
	Dap Coat 5020/CA-S Catalyst	Deutsch A/C Products Co.		
	Dap Coat 1001	Deutsch A/C Products Co.		
	Turco 522-66	Turco Product, Inc. Chem-Mill and Coatings Div. 24600 S. Main St. Wilmington, CA 90744		
	Organoceram 1-2050	Hitco, Organoceram Div. U.S. Polymeric P.O. Box 2187 700 E. Dyer Rd. Santa Anna, CA. 92707		
	Protex, Paper 50	Mask-Off Co. 345 W. Maple Monrovia, Calif. 91016		
Putty, noncuring zinc chromate	MIL-S-11030 Type I 782.9 grey 787.9 red	Presstite Engr. Co. St. Louis, Missouri		Vacuum sealing tape
	G.S. 43 or 213	General Sealants		Vacuum-sealing tape
	Foster 9B2 MIL-P-8116	Foster Co.		For fiberglass parts only

Table 4-5.–(Continued)

Materials	Manufacturer's no. or specification no.	Supplier	Federal stock no.	General remarks
Release agent	Garan 225	Ram Chemical, Inc. Gardena, Calif.		Use for mold or tool release
	Frekote 33	Frekote, Inc. Indianapolis, Ind.		
	Release All-100	AirTech International		
	Petrolatum VV-P-236	Any Source		
Release film	FEP or TFE 0.0015 or 0.002 in. thick	DuPont Los Angeles, Calif.		Use as parting film on caul plate, tooling
	Teflon, perforated 0.0015 or 0.002 in. thick	Universal Plastics Seattle, Wash.		
	Modified halocarbon (TFE), solid and perforated, E3760 0.0015 or 0.002 in. thick	Air Tech. International		
	Coated fiberglass peel ply, nylon style 1B 301-F58	Coast Mfg. & Supply Co.		
	Dacron peel ply	Burlington Ind. Fabric New York		

Table 4-5.—(Continued)

Materials	Manufacturer's no. or specification no.	Supplier	Federal stock no.	General remarks
Solvents, general purpose	Acetone O-A-51	Any source	9G6810-00-189-4796	Use for general purpose cleaning not for use in vapor degreasing tanks)
	Methylethyl Ketone TT-M-261	Any source	9G6810-00-281-2785	
WARNING: Note precautions that should be used when handling solvents. See section 1.3	Tricholoroethane 0-T-620	Any source		May be used for general purpose cleaning or vapor degreasing. DO NOT use to clean titanium because of hydrogen embrittlement.
	Methylisobutyl Ketone TT-M-268	Any source	9G6810-00-226-3785	Use for general purpose cleaning (not for use in vapor degreasing tanks)
	Toluene TT-T-548	Any source	9G6810-00-281-2002	
	Xylene TT-X-916, grade A or B	Any source	9G6810-00-257-2480	
	Aliphatic naptha TT-N-95	Any source		
	Denatured alcohol MIL-A-6091	Any source		
	Isopropyl alcohol TT-I-735	Any source		
Solvents (cont.)	Aromatic naptha TT-N-97, type I	Any source		Use for general purpose cleaning (not for use in vapor degreasing tanks)
	Ethyl acetate TT-E-751	Any source		

Table 4-5.–(Continued)

Materials	Manufacturer's no. or specification no.	Supplier	Federal stock no.	General remarks
Tapes	Plastic tape, nylon (855)	3M		Use for general purpose aid in surface preparation, layup for bonding and adhesive flash control
	Aluminum tape (P12) MIL-A-148	Permacel L-T-80		
	High temperature masking tape UU-T-106 Mystic 6325	Borden Chemical Co.		
	Double-back tape # P50	Permacel		
	Lead tape Scotchbrand 420	3M		
Vacuum bag film	PVA	Reynolds Co. Grottoes, Vir.		Plastic film used for vacuum bags over bonding area during cure operation.
	Mylar 2 Mil 106 in.	DuPont		
	Nylon 2 or 3 Mil	DuPont		
	Nylon, Vac-Pac # 8171 2 or 3 Mil	Air Tech International		
	Tedlar 200 SG40TR (PVF)	DuPont		
Vacuum bag sealer	Zinc chromate sealing compound, no. 5144	Schnee Morehead Chemical Irving, Texas		Vacuum-sealing tape
	Butyl tape	PTI Dayton, Oh		Vacuum sealing tape

Table 4-5.–(Continued)

Materials	Manufacturer's no. or specification no.	Supplier	Federal stock no.	General remarks
Miscellaneous	Cheesecloth[a] oilfree, lintfree, CC-C-440	Any source	8305-00-262-3321	Use to apply acids, solvents; for hand rinsing, etc.
	Cloth, rumple, purified, polishing fabric, lintless, No. 301	Kendall Co.		
	Kraft paper UU-P-268	Any source		Use to wrap detail parts after cleaning for temporary storage
	Osnaburg cloth CCC-C-429	Any source		Use to absorb excess resin during cure
	Armalon 95-063 Teflon-coated glass fabric	DuPont		
	TFE impregnated fiberglass STL & STM type	Conn Hard Rubber Co.		STL is perforated STM is nonperforated
	Glass fabric 181 Volan A 191 Volan MIL-C-9084	Any source		
	Aluminum powder type III, grade F MIL-A-512	Any source		Use as a resin filler
	Pumice SS-P-821 FF grade or finer	Any source		

Table 4-5.–(Concluded)

Materials	Manufacturer's no. or specification no.	Supplier	Federal stock no.	General remarks
Miscellaneous (cont)	Cab-O-Sil	Cabot Corp. 125 High St. Boston, Mass 02110		Use as filler to thicken resins or acids
	Dry ice		6830-247-0619	
	pH paper	Any source		To check acid or alkaline conditions
	Litmus paper	Any source		To check acid or alkaline conditions

[a]Cheesecloth, shall conform to the following analysis when tested per CCC-T-191, Method 2611 (extraction shall be made on solvents *listed)*:

1. Grease and oil content $\leqslant$1.0% of dry weight based on carbon tetrachloride extraction.
2. Acetone soluble content is 5.0% max. of dry weight.
3. pH of water extraction is 5.0 to 7.5.
4. Water soluble content is 1.0% max. of dry weight; *not applicable to gloves.*

6. The thickness of the primer is essential to obtaining acceptable bond properties. Dried film thickness may vary from 0.0001 to 0.001 inch or as specified by the supplier, depending on the type of primer system used. Film thickness may be checked using an isometer (e.g., Foster Isometer 2.082, West Germany) or similar instrument, e.g., Permascope, Dermatron.

7. If bonding is not completed immediately, protect the primed details by wrapping in wax-free Kraft paper, black polyethylene film, or a comparable material.

Preparation and Application of Adhesive Primer–Spray Method

1. Condition primer as in section 4.3.1, Nonspray Method of Primer Application, steps 1, 2, and 3.

2. The type of primer, solids content, viscosity, solvents, etc., all affect the spray conditions to be used.

   Follow manufacturer's recommendations for spray procedures, or use the following suggested conditions.

Spray gun	DeVilbiss MBC
Air cap	No. 78
Needle-nozzle	AV-15-FX
Line pressure	30 to 80 lb
Fluid flow	Approx. 5 fluid oz/min
Pot pressure	1 to 2 lb if applicable
Distance from panel	9 to 14 inches
Primer thickness	0.0001 to 0.001 inches (depending on primer type)

NOTE: Pressurized bottles such as the "Preval" may be conveniently used to spray primer on small areas, see figure 4-1.

3. Spray primer in a uniform coating to the cleaned faying surfaces.

4. Air dry or air dry/bake per manufacturer's brochure.

5. Check thickness and protect surface as in section 4.3.1 (Nonspray Method of Primer Application), steps 6 and 7.

4.3.2 APPLICATION OF FILM ADHESIVES

1. Condition to ambient room temperature before opening the wrapper. Record adhesive "out" time and keep a cumulative record. Requalify or discard when the allowable out-time specified in the specification has been exceeded.

2. Solvent-clean cutting tools, templates, and other equipment used for laying out the adhesive.

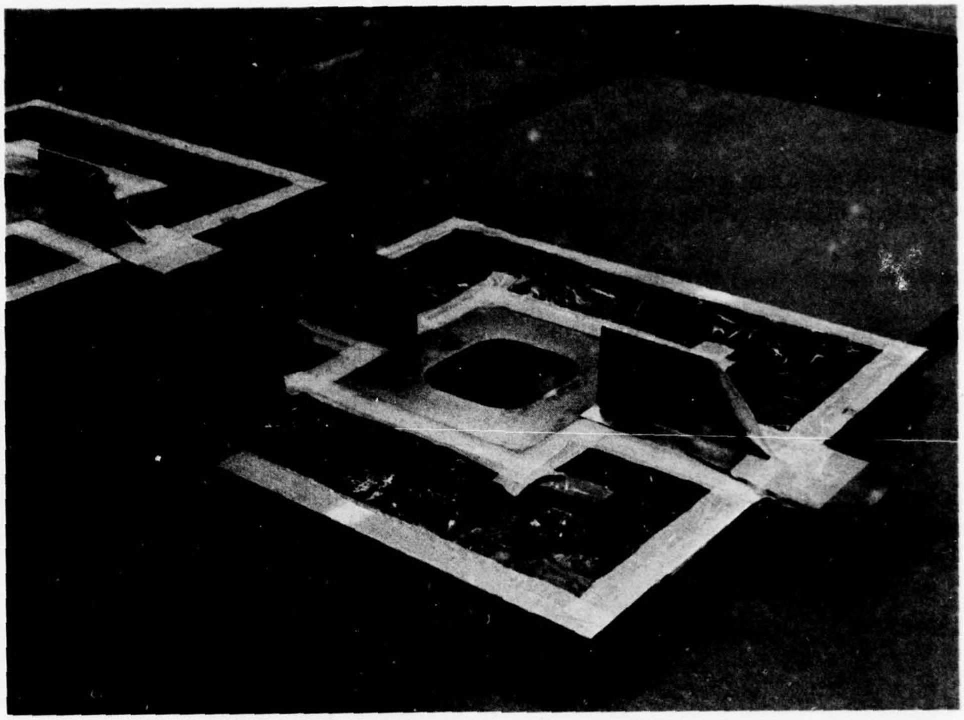


Figure 4-1.—Preval Pressurized Spray Bottle to Apply Adhesive Primer

CAUTION: **DO NOT Touch the Adhesive with Bare Hands or Other Parts of the Body. Clean White Gloves Must Be Worn When Handling Cleaned Details, Adhesives, or Other Parts During Lay-up.**

3. For metal-to-metal and metal-to-core bonds, apply a layer of adhesive film to one of the prepared surfaces to be joined. A small amount of heat may be applied to tack the adhesive to the metal part.

4. Do not fold, stretch, or otherwise thin the adhesive.

5. Leave the separator sheet on the side of the adhesive exposed to the atmosphere as a temporary protection cover.

6. Press the adhesive smoothly in place. Avoid air entrapment.

7. Trim the adhesive film to leave approximately 1/8-in. excess beyond the joint perimeter. The adhesive film must not be less than net (i.e., not less than the size of the part). The details may be used as templates for cutting the film.

8. **Remove the remaining separator sheet just prior to assembly of the details.**

9. Prepare for cure as specified in section 7.11, Vacuum Bagging.

4.3.3 PREPARATION AND APPLICATION OF LIQUID/PASTE ADHESIVES

1. Allow any adhesive removed from refrigerated storage to reach room temperature prior to opening the container.

2. Weigh amount per manufacturer's instructions or as noted in table 4-3.

   NOTE: Mix only the amount of material that can be used with the specified working life. A large quantity of mixed material will shorten the working life (exothermic reaction) and hasten the gel time.

3. With preweighed or premixed component materials, follow manufacturer's mixing and application instructions.

4. Mix to homogeneous mixture as to color change or uniform color. Mix slowly to minimize air entrapment.

5. Apply uniform coating to each faying surface by trowel, brush, roller, etc.

6. Assemble the details.

7. Secure in place.

8. Bag or apply pressure per section 7.11, Vacuum Bagging.

9. Cure as specified by the manufacturer or as given in table 4-3.

4.3.4 PREPARATION AND APPLICATION OF POTTING COMPOUNDS

1. Allow refrigeration-stored materials to reach room temperature before opening to prevent moisture condensation.

2. Mix potting compound materials per the mixing ratios in table 4-3 or as specified by the manufacturer's instructions.

3. Apply the mixed materials by injection, trowelling, or other suitable method.

   NOTE: Mix only the amount of material that can be used with the specified working life. Large quantity of mixed material will shorten the working life (exothermic reaction) and hasten the gel time.

4. Cure potting materials per table 4-3 or as specified by the manufacturer's instructions.

5. Do not handle potted assemblies until they have been cured.

4.3.5 PREPARATION AND APPLICATION OF CHROMATE CONVERSION COATING, MIL-C-5541, CLASS IA (e.g., ALODINE 1200)

Any repair process which bares the original structure requires a protective treatment. The treatment acts as a paint base and corrosion inhibiter. Aluminum alloys of the original structure require subsequent conversion coating in cases where repair processes expose areas to possible corrosion.

NOTE: Instructions given in the following paragraphs apply specifically to Alodine 1200, which is one of the more commonly used conversion coatings. If another coating listed in MIL-C-5541 is to be used, follow the manufacturer's recommended application instructions or your locally prepared specification.

CAUTION: Cloths or other materials used to apply the conversion coating should be rinsed out thoroughly in water after use and deposited in an approved safety container. Dispose of chromate conversion and rinse solutions per local safety and health regulations.

Preparation of Alodine 1200 Solution

1. Mix by rolling the contents of each container of Alodine 1200 powder thoroughly on clean paper prior to withdrawal of fraction to be used.

2. Add 3 oz of Alodine 1200 powder to each gallon of water used.

3. Mix in stainless steel or acid-resistant container. (Do not use lead or glass.)

4. Stir well until powder is dissolved.

   NOTE: Compliance with mixing procedure is required for a satisfactory solution. A small amount of material that may settle out of solution can be disregarded.

5. Allow the solution to stand at least 1 hour before use.

   NOTE: A dirty solution is unsatisfactory. Prepare in small quantities and discard after use. If nondistilled water is used, adjust pH range from 1.50 to 2.00 by addition of nitric acid. Check range by the use of pHydrion paper #60781. Add no wetting agents or other materials to this solution.

Prepare the Surface For Alodine (Except Adhesive Bonding Surface*)

1. Mask all surfaces likely to be contaminated by running, dripping, or splashing of the solution. Painted, anodized, or previously alodined surfaces need not be masked.

CAUTION: Chromate conversion coatings must not be allowed to come in contact with high strength steels as they may cause hydrogen embrittlement.

2. Seal or plug all holes, gaps, and inlets to assemblies containing honeycomb or foam plastic with suitable sealing or caulking material or rubber plugs to prevent entry of any solution.

3. Clean area to be chromate conversion coated with a liquid solvent degreaser by using a clean brush or oil-free gauze or cloth. Dry with warm air or wipe dry.

4. Remove the existing organic and inorganic finish from the repair area. Remove the hydraulic fluid resistant finish at the same time the inorganic coating is stripped. Strip the inorganic coatings such as anodize or alodine mechanically with a nylon abrasive wheel or aluminum oxide paper. Clean all signs of organic and inorganic coatings until a uniform, bright, shiny aluminum surface is obtained.

5. Vacuum or wipe the abraded area with dry, clean cheesecloth to remove loose particles and residue.

6. Wipe with cheesecloth dampened (not saturated) with solvent. Repeat using clean cheesecloth until no visible residue transfers to the cheesecloth.

7. Allow to dry for a minimum of 15 minutes.

*Where the Alodine 1200 is applied on a surface to be adhesively bonded, the surface shall be prepared per instructions in section 5.0 prior to application of the alodine.

Application of Alodine 1200

1. Apply Alodine 1200 evenly and liberally with a fiber or nylon brush, clean cheesecloth, or a cellulose sponge.

2. Allow the solution to remain for 3 to 4 minutes to form a bronze or golden brown coating. Keep the treated area from drying by gently blotting with cheesecloth moistened with Alodine 1200.

3. Rinse with clean water by gently contacting the treated surface with wet (not saturated) clean cheesecloth. Contact (blot) for 1 to 2 minutes and repeat.

   CAUTION: Exercise care when rinsing and contacting treated surface to avoid scratching or removing the freshly formed coating.

4. Gently contact the surface with clean dry cheesecloth to absorb excess liquid. Repeat as necessary.

5. Check crevices with blue litmus paper for possible acid contamination. If litmus paper turns red, acid is still present and steps 3 to 5 should be repeated.

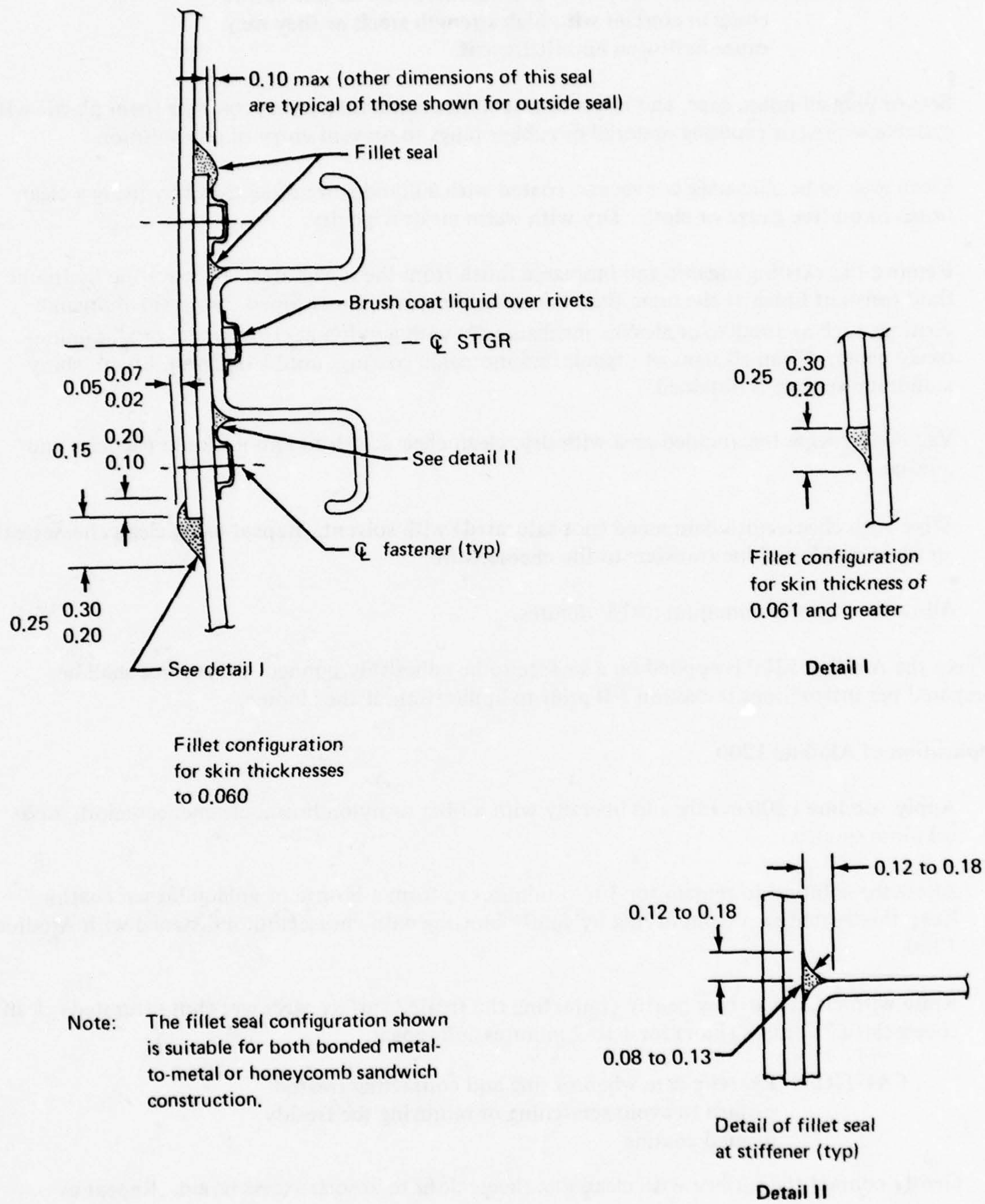


Figure 4-2.—Fillet Sealing of Bonded Repairs

6. Room temperature air dry or hot air (140° F maximum) dry.

CAUTION: Dispose of chromate conversion and rinse solutions per local safety and health regulations.

4.3.6 PREPARATION AND APPLICATION OF SEALANTS AND AERODYNAMIC SMOOTHERS

1. Allow refrigeration-stored materials to reach room temperature before opening to prevent moisture condensation.

2. Prepare the applicable environmental sealant or aerodynamic smoother compound according to manufacturer's or specification instructions.

3. Observe safety precautions.

4. Remove adhesive flash at the edge of bonded joints as required. Leave approximately a 45° fillet for sealing of edge.

5. Wipe clean with solvent.

6. Apply conversion coating (see sec. 4.3.4) to aluminum surfaces that will be finished with an organic coating. Do not treat aluminum surfaces that will not receive organic finish, titanium surfaces, and fiberglass surfaces.

7. Apply sealant to or apply aerodynamic smoother to all repair adhesive bond lines (see fig. 4-2).

8. Cure the sealant or smoother per applicable instructions or specifications.

4.3.7 PREPARATION AND APPLICATION OF FINISH COATINGS

1. Clean the repair area in accordance with the applicable T.O., e.g., T.O. 1-1-1.

2. Prime the surface with the applicable primer according to the specific –23 T.O. callout; also refer to T.O. 1-1-4 and T.O. 1-1-8.

3. Top coat with the applicable finish as required per the specific –23 T.O. callout; also refer to T.O. 1-1-4 and T.O. 1-1-8.

4.4 MATERIAL COMPATIBILITY

Some adhesive systems are more sensitive and less compatible with certain hand surface-preparation procedures than others. For example, some adhesive systems provide poor bond durability with the 2% HF method, section 5.3.2 while others give satisfactory bonds. If the compatibility of the adhesive system to surface preparation method is questionable, either physical and chemical tests should be conducted by laboratory personnel or another surface preparation method or adhesive selected. The wedge test described in section 4.4.1 is a convenient and discriminating test for the 250° F-curing epoxy adhesives. This test measures crack growth in a high humidity environment. If incompatibility exists, the crack growth in one hour will be high (usually more than 1 inch) as compared to the growth for a compatible system (usually less than 0.20 inch). The climbing drum peel test described in MIL-A-25463 is a discriminating test for RT- and 350° F-curing adhesives. Surface compatibility is indicated by cohesive failure modes in contrast to adhesive failure modes for incompatible systems.

4.4.1 WEDGE PANELS, SPECIMENS, AND TEST PROCEDURE

The configuration of the wedge test specimen assembly and the specimen details are shown in figure 4-3. The laminated assembly is 6 by 6 inches. The metal adherends are nominally 0.125 inch thick. A strip approximately 0.75 inch wide on one edge of the panel is left unbonded. After bonding, five 1-in.-wide specimens are machined or saw cut from the panel. Sand one edge. The specimens are then marked with an identification for exposure. The testing procedure for the specimens consists of the following:

1. Precrack the unbonded end of the specimen by inserting a wedge as shown in figure 4-3. Insert the wedge by using several light taps with a hammering device. Do not attempt to insert the wedge with a single striking blow.

2. Position the wedge so that its end and sides are approximately flush with the specimen ends and sides.

3. Using 10- to 30-power magnification and adequate illumination, locate and mark the tip of the initial crack with a fine stylus or scribe.* Looking closely, a change in the adhesive to a lighter color can usually be seen right at the crack tip. Also locate and mark the reference point of crack initiation. This is the point at which the shoulder of the wedge contacts the specimen surface, i.e., approximately 0.75 inch from the specimen end. Measure and record the initial crack length.

4. Expose the wedged specimens to the selected environmental conditions (e.g., $120^{\circ} \pm 5^{\circ}$ F and 95% to 100% relative humidity) for the specified time (e.g., 1 hour, 4 hours, 72 hours, 14 days, or 30 days). The water used to maintain the humidity must not contain more than 200 ppm total solids. For compatibility screening tests, exposure time of 4 hours is adequate.

5. Remove the specimens from the environment. Mark and measure the increase in crack length to 0.01 inch within 2 hours after removal.

6. Failure modes may be determined by splitting the specimen open at the completion of the final crack growth measurement and examining the surface. The percentage of adhesive versus cohesive failure in the exposed crack growth region should be recorded.**

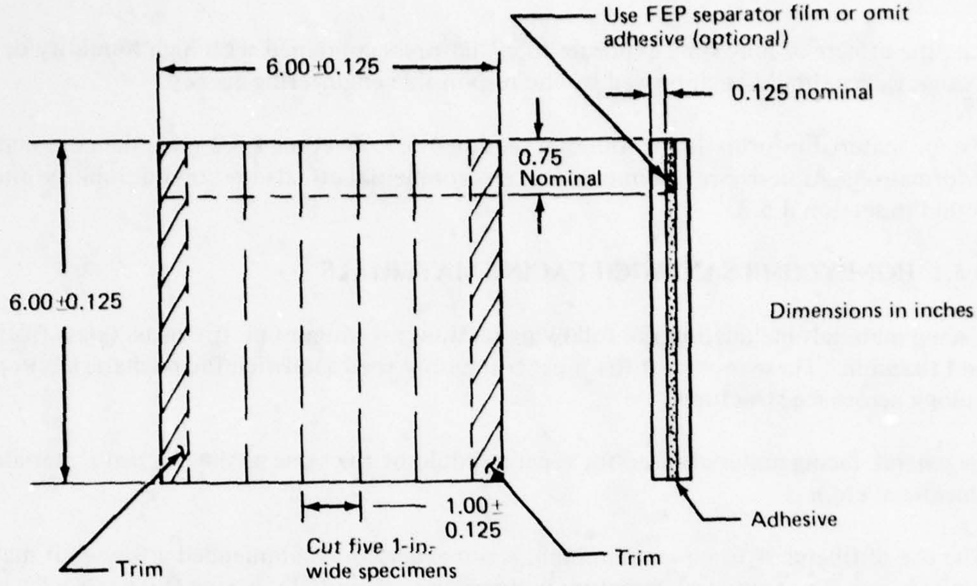
4.5 MATERIAL PROPERTY DATA

Mechanical strength property data for facing, core, and adhesive materials are presented in various military specifications, handbooks, and reports. The locations of many of these data sources are identified in the following paragraphs.

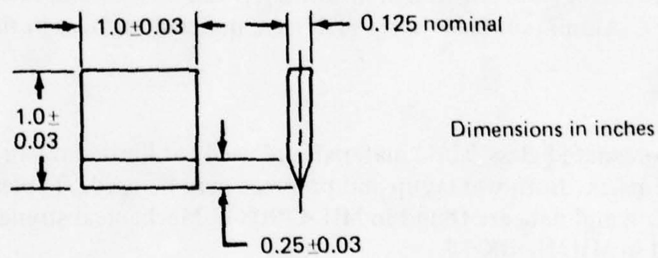
The data may be presented either as typical test values or as minimum properties. Minimum properties should be used for design. It may be appropriate to reduce the properties further to allow for such factors as elevated service temperatures or progressive degradation due to the operating environment.

*For salt spray exposure of extended duration, use a triangular file to enlarge scribe mark for easier reading.

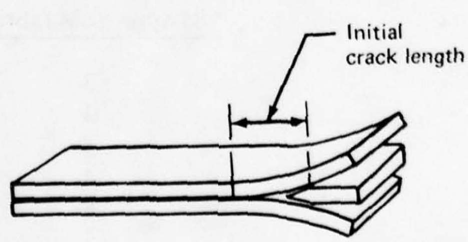
**For accept/reject criteria, see sect. 7.5.3.



Wedge Test Specimen Assembly



Aluminum or Stainless Steel Wedge



Wedged Crack Extension Specimen

Figure 4-3.—Wedge Test Specimen Configuration

e.g., the effects of long time exposure to cyclic stress combined with high humidity or salt spray. Design values should be approved by the responsible engineering agency.

Facing material information is found in section 4.5.1. Section 4.5.2 gives the core materials information. Adhesive requirements and environmental effects on bond durability information are found in section 4.5.3.

4.5.1 HONEYCOMB SANDWICH FACING MATERIALS

Facing materials included in the following sections are aluminum, fiberglass (glass-fiber-reinforced), and titanium. These represent the most commonly used sandwich facing materials in present technology aerospace structures.

In general, facing materials used for repairs should be the same as the original material (type, alloy, thickness, etc.).

The use of fiberglass to repair aluminum is not generally recommended although it may be used in limited cases on compound curvature parts or on parts initially having fiberglass edge closures or inner skins. This type of repair will be defined or authorized by the responsible engineering agency.

Aluminum

Aluminum facing data and design information can be found in MIL-HDBK-5B and Specification QQ-A-250. Aluminum face sheets shall have nonclad surfaces in the bondlines whenever possible.

Fiberglass

Resin-impregnated glass fabric materials are used for limited repair applications to compound curvature parts. Both wet layup and prepregs may be used. Typical glass fabric style 181 and 120 information and data are found in MIL-C-9084. Mechanical strength data and design information are found in MIL-HDBK-17.

Use the following guide when using glass fabric overlay patches for the number of replacement piles required.

Original aluminum skin thickness (inches)	Number of plies of 181-type glass fabric
0.010 or less	3
0.012	3
0.016	4
0.020	4
0.022	5
0.025	5

Following the repair, the fiberglass surface should be finished as follows: Seal the repair patch surface with sealer (e.g., the repair resin mix). Scrape excess resin off before it gels. Cure the sealer and apply chemical and solvent resistant primer and top coat per the applicable T.O.

Titanium

Titanium facing information and data can be found in MIL-HDBK-5B and specification MIL-T-9046.

4.5.2 HONEYCOMB CORE MATERIALS

Core information can be obtained from MIL-C-7438 for aluminum core, and MIL-C-8073 for fiberglass core. Fibrous nylon base (e.g., Nomex) core data can be found in Specification AMS-3711.

Aluminum Honeycomb Core

Aluminum core materials are available in various cell sizes, densities, and alloys. A few typical callouts are given in table 4-1. Corrosion-resistant-type core is recommended for replacement in all repairs regardless of original core type in aluminum panels.

Aluminum 5056 alloy core may be substituted for 5052 core.

The replacement core should match the core cell size and density of the original. In situations where the designated core density or cell size is not available, use of the next higher density core with the same cell size is permissible.

Nonmetallic Honeycomb Cores

Both glass-fabric-reinforced and fibrous-nylon-base nonmetallic honeycomb cores may be used for repairs. In cases where nonmetallic core is substituted for original aluminum core, it should equal or exceed the original in stiffness and strength.

4.5.3 ADHESIVES

Mechanical property data for adhesive systems are available from several sources. Examples of these are the adhesive supplier, the airframe manufacturer that utilizes that particular material, and military specifications such as MIL-A-25463 or MMM-A-132. Care must be taken that design values adequately allow for degradation due to environment or the effect of elevated temperatures.

The particular surface preparation method is a very important parameter in determining the allowable design strength. Many of the commonly used adhesives were tested with various hand cleaning methods in Air Force Contract F33615-73-C-5171. These data are reported in AFML-TR-75-158. The presented information gives typical strength plots for various bonded joint overlap lengths. These are typical test data. The design values to be used should be approved by the responsible engineering authority.

4.5.4 POTTING COMPOUNDS

Mechanical and physical properties of potting compounds should be obtained from the material supplier or from the airframe manufacturer using that particular material system.

4.6 ADHESIVE RECEIVING ACCEPTANCE TESTS

Where practical, it is recommended that the adhesives to be used for repair be tested by the user to ensure specification compliance. The following is a guide to the number and types of tests that should be used.

1. The acceptance tests of table 4-6 are recommended on each sample of each lot of adhesive.

2. Lap shear tests should be performed at RT and the highest use temp., e.g. 180° F for 250° F curing adhesive. Peel tests may be performed at R.T. or -65° F.

3. In addition to the tests specifically listed for quality assurance, any other test described in the applicable specification may be used to ensure that shipments of adhesive conform to the requirements of this specification and are comparable to material previously qualified.

4. The test specimen configurations are described and shown in the following sections.

Table 4-6.—Assemblies and Specimen Requirements

Test	Bonded assemblies per sample	Specimens per sample	Specimen configuration
(1) Lap shear	1	5	See figure 4-5
(2) Metal peel	1	3	See figure 4-7
(3) Honeycomb peel	1	3	See figure 4-9
(4) Film weight	–	2	*

*(a) Cut 2 specimens of material across the width of the film. Cut specimens approximately 6 x 6 inches. Determine the area to the nearest 0.1 square inch.

(b) Remove separator sheets from the film and weigh film to nearest 0.1 grams.

(c) Report average weights to nearest 0.001 lbs/ft^2.

Lap Shear

1. Test panel blank

   - Material and thickness for blanks shall be 0.063 inch thick 2024-T3 aluminum alloy QQ-A-250 (bare).

   - The blanks shall be nominally 6 by 7 inches.

   - The blanks shall be flat within 0.010 inch.

2. Test panel assembly

   - Adhesive bonding material and processing instructions shall be as designated in the applicable specifications.

   - Two test panel blanks shall be bonded to the configuration shown in figure 4-4.

3. Test specimen

   - Cut the test panel assembly as shown in figure 4-5.

4. Metal-to-metal lap shear test

   - Test the specimens to the procedures described in MMM-A-132.

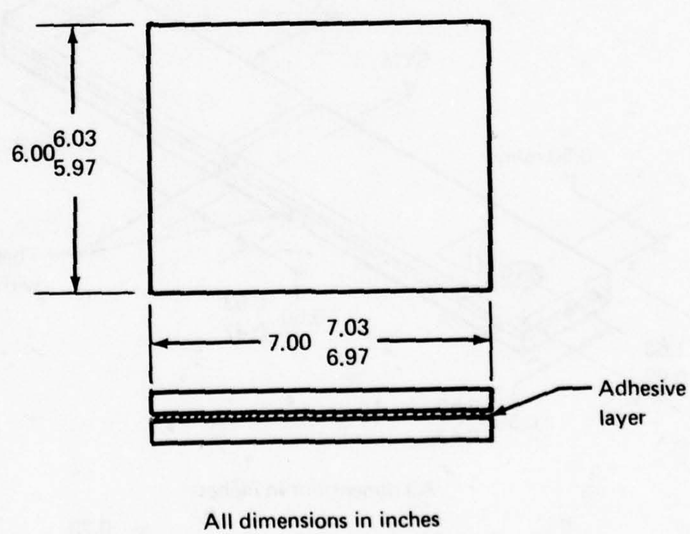


Figure 4-4.—Test Panel Assembly

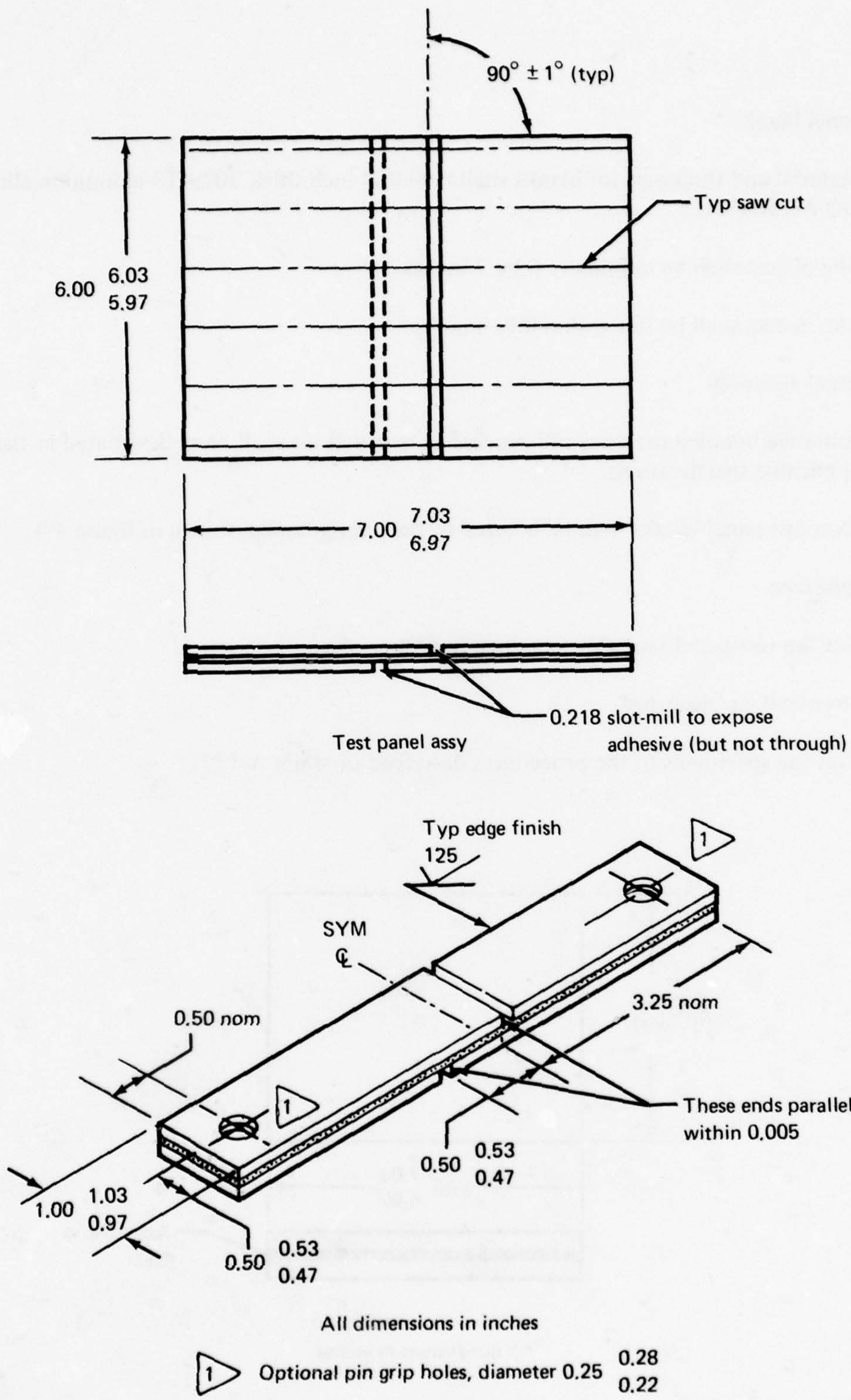


Figure 4-5.—Lap Shear Test Specimen Configuration

Metal-to-Metal Peel

1. Test panel blank

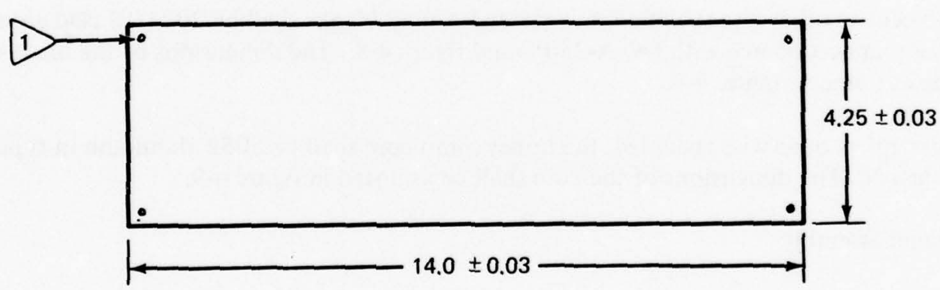
   - Except as otherwise specified, the material for all blanks shall be 2024-T3 clad aluminum alloy in accordance with QQ-A-250/5.
   - Blank dimensions shall be as shown in figure 4-6.

2. Test panel assembly

   - Adhesive bonding material and instructions shall be as designated in the applicable specification.
   - Two test panel blanks shall be bonded together as shown in figure 4-7.
   - Identify each test panel assembly and specimen as necessary.

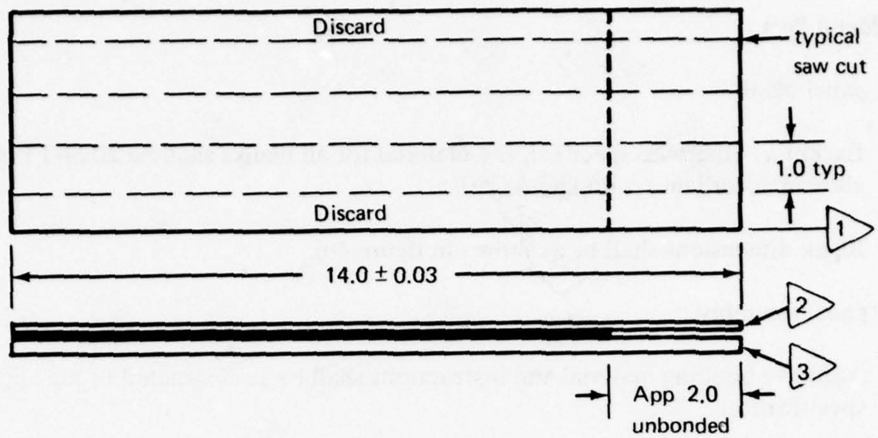
3. Climbing drum peel test

   - Test the specimens to the procedures described in MIL-A-25463.
   - The curing temperature and time at temperature of the adhesive bond shall be as specified and shall be measured by the use of a fine wire thermocouple (no. 30 maximum) embedded in the adhesive flash immediately adjacent to the bondline.



1 Holes, 4 places, 0.125 D centered approximately 0.25 inch from edges.

Figure 4-6.—Metal-to-Metal Peel Test Panel Blank



1 Trim discard edges shall be 0.50 inch minimum. Cut three specimens 1.00 ± 0.03 inches wide.

2 0.020 inch

3 0.040 inch

Figure 4-7.—Metal-to-Metal Peel Test Panel Assembly and Specimen

Honeycomb Peel

1. Test panel blank

- Except as otherwise specified, the material for all blanks shall be 2024-T3 clad aluminum alloy in accordance with QQ-A-250/5 and figure 4-8. The dimensions of the blanks shall be as noted in figure 4-8.

- Except as otherwise specified, the honeycomb core shall be 5052 aluminum in type 4-40, Class N. The dimensions of the core shall be as noted in figure 4-9.

2. Test panel assembly

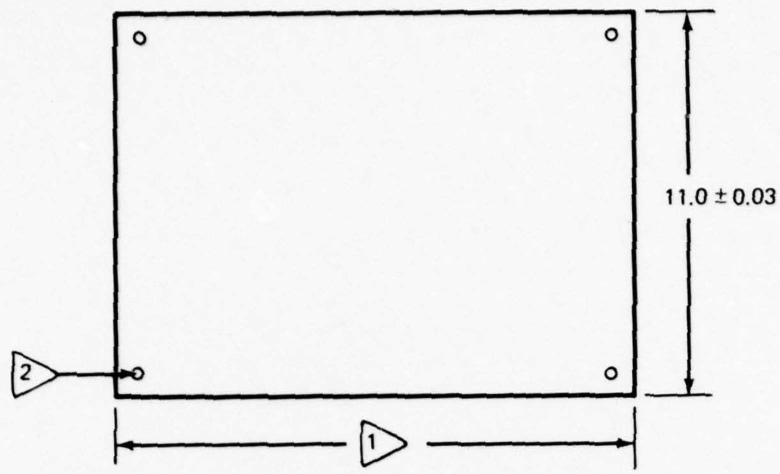
- Adhesive bonding material and instructions shall be as designated in the applicable specification.

- Two test panel blanks and core shall be bonded into an assembly as shown in figure 4-9.

- Identify each test panel assembly and specimen as necessary.

3. Honeycomb peel test

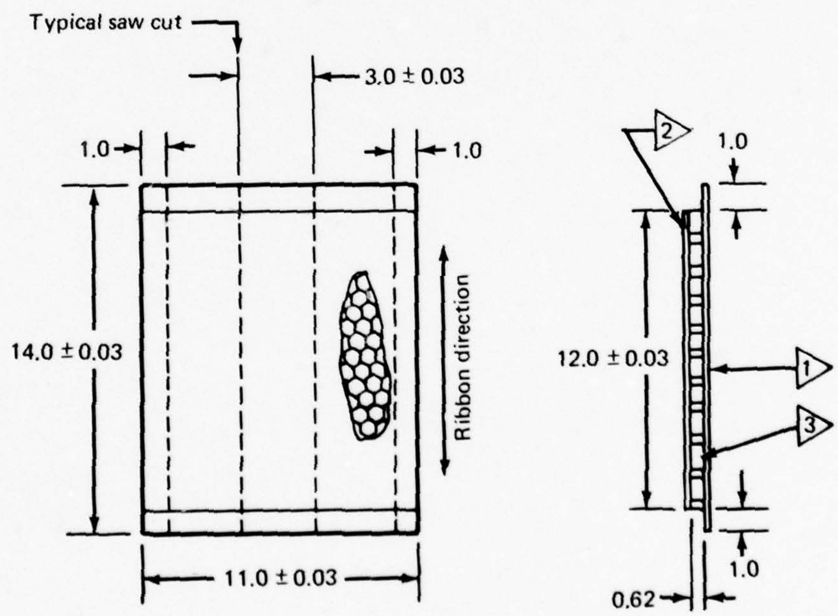
- Test the specimens to the procedures described in MIL-A-25463.



1 14.00 ± 0.03 inches
12.00 ± 0.03 inches

2 Holes, 4 places, 0.125 D centered approximately 0.25 inches from edges.

Figure 4-8.—Honeycomb Peel Test Panel Blank



1 Peeling face panel—11.0 x 14.0 x 0.020 inches
2 Backing panel—11.0 x 12.0 x 0.020 inches
3 Core—11.0 x 12.0 x 0.625 inches

Figure 4-9.—Honeycomb Peel Test Panel Assembly

5.0 SURFACE PREPARATION PROCEDURES

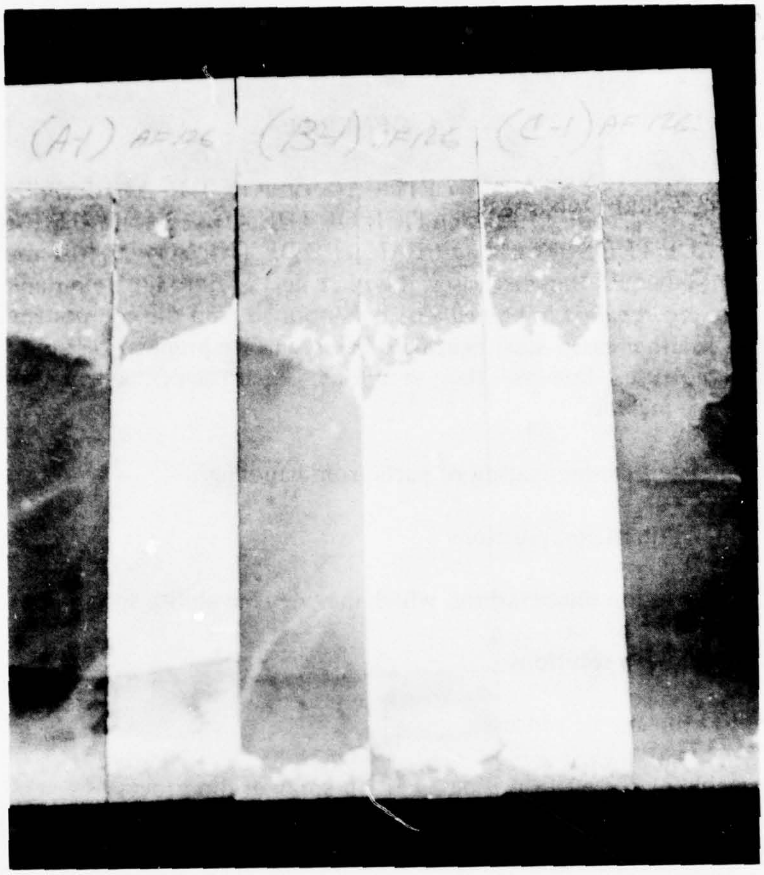
5.1 GENERAL

SURFACE PREPARATION IS THE MOST CRITICAL STEP IN THE ADHESIVE BONDING PROCESS. THE ADEQUACY OF PREPARATION OF THE ADHEREND SURFACES WILL LARGELY DETERMINE THE SUCCESS OR FAILURE OF THE BOND. It is imperative that the best surface treatment be used. In many cases, it will be necessary to use a nontank or hand procedure. This is the case in which a repair is to be made on a component and the component cannot be immersed in a tank. In other cases, such as at field bases, surface preparation tanks may not be available. Where tanks can be used, however, they should be. Their use offers many advantages over hand procedures. These include:

- Reduced possibility of contamination of parts from handling
- Better control of solution compositions
- Better control of solution temperatures, which includes the ability to use hot processes
- Closer control of time in solutions
- Precise control of the anodic process
- More effective cold or hot water rinsing by either spray or dip processes
- Time and temperature control of drying ovens
- Reduced cost due to more efficient multiple part processing and improved repair durability

In order to obtain durable bonds under service environments, surface preparation procedures outlined in this section should be used. The procedures given are recommended guides and the preferred method of surface preparation should be used whenever feasible. Use of marginal methods such as abrading plus solvent cleaning gives bonds with poor environmental durability.

The difference between a marginally and a properly prepared bond surface is illustrated in figures 5-1 and 5-2. Flat strips of aluminum were cleaned using either abrasion and solvent wiping or were prepared by phosphoric acid anodizing. Pairs of the strips were bonded together. The end of the laminated strips were forced apart by inserting a small metal wedge. The strips were then placed in a chamber and exposed to 140^{o} F and a high humidity. The rate that the split or crack propagated was measured. The strips were subsequently split apart and the surfaces examined. The crack in the solvent cleaned specimens grew quite rapidly. The adhesive pulled away from the metal surface as shown in figure 5-1. By contrast, the crack growth of the anodized strips was almost nil. When pulled apart, the failure was in the center of the bond, i.e., cohesive, rather than from the metal. This is shown in figure 5-2. The results of this type of test correlate well with satisfactory or unsatisfactory service performance. Admittedly, more time is required to prepare the bond surface properly. The pay-off, however, is in having a bond that will not fail, in a short time, after the repaired part has been returned to service.



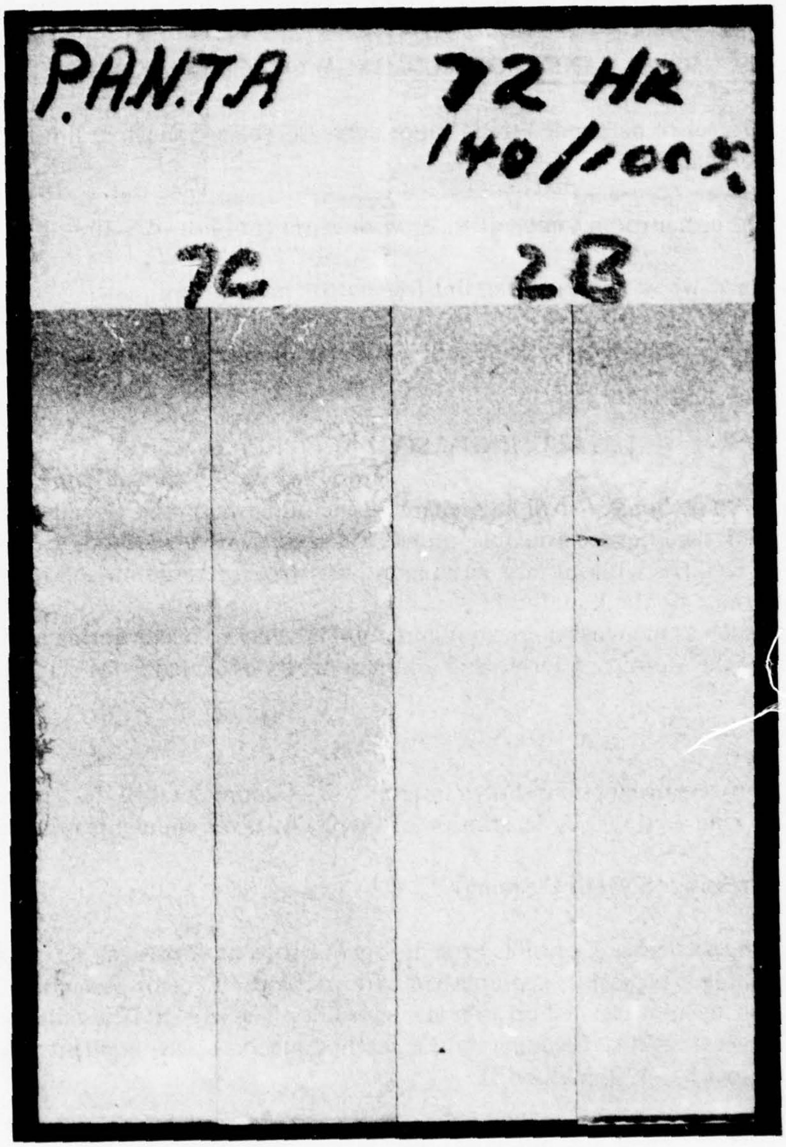
Note how the adhesive pulled away from the metal (adhesive failure).

Figure 5-1.—Aluminum Failure Surfaces—Solvent Cleaned Before Bonding

In cases where adequate surface preparation facilities are not available, prepared skins have been used to an advantage. These skins are cleaned at a base facility in accordance with standard approved methods. The clean skin is then primed and bonded to a layer of approved adhesive film with a nylon peel ply on the other side of the adhesive. This prebonded skin is stored until required for use. It is then cut to required size, the nylon peel ply removed, and the skin bonded in place. On-site cleaning of the part to be repaired is still required. However, the amount of on-site cleaning is minimized.

Some materials used in bonded structural repairs and surface preparation methods are toxic and flammable. Exercise care in using these materials. Follow the applicable government regulations, and observe the following:

- **Use explosionproof electrical equipment.**
- **Keep repair area well ventilated.**
- **Keep solvents and cleaners in safety containers.**



Failure occurred within the adhesive (cohesive failure.)

Figure 5-2.—Aluminum Failure Surfaces—Phosphoric Acid Anodized before Bonding

- Avoid breathing adhesive or cleaning fluid fumes.
- Wear rubber gloves and protective clothing when handling acid and caustic cleaning solutions.

DO NOT allow acids to come in contact with the surface of high strength steels.

5.2 CLEANING OF ALUMINUM CORE FOR BONDING

1. Clean core surfaces to be bonded using vapor degrease, solvent flush, or lint-free cloth moistened with trichloroethane.
2. Dry the core at either room temperature or with warm (not hot) dry air (e.g., 150° F max).
3. Handle core only when wearing clean lint-free cotton gloves.
4. If core is not used immediately, protect by wrapping or covering with clean, wax-free Kraft paper.

5.3 ALUMINUM SURFACE PREPARATION

Aluminum surfaces to be bonded shall be prepared using immersion tank cleaning or nontank hand cleaning. Where tank facilities are available, immersion tank cleaning methods are recommended. For fixed structures or facilities without tank equipment, use the preferred nontank (acid) cleaning methods. The alternate nontank method (no acid) is for use only with structures internal to the honeycomb panel such as in areas where contamination is likely to occur during acid cleaning. Table 5-1 illustrates the various preferred and alternate methods available for surface preparation.

5.3.1 TANK PROCESSES

Abbreviated tank processing steps are shown in table 5-2. A more detailed description of these items is given in the following sections. A description of the facilities requirements is given in section 8.3.1.

5.3.1.1 Vapor Degreasing (Solvent Cleaning)

Where loose adhering dirt, grease, or oil is present, organic solvent degreasing should be employed. Simple surface cleaning is typically accomplished with trichloroethane or perchloroethylene. The solvent should be changed or cleaned on a regular schedule. The solvent is usually heated to a minimum of 185° F for best results. Cleaning by this method meets the requirements for solvent vapor cleaning according to TT-C-490, method II.

CAUTION: **These Chlorinated Hydrocarbon Solvents are Toxic, Anesthetic, and Present a Fire Hazard Unless Properly Used and Maintained. Avoid Allowing Solvent to Contact the Skin and Breathing the Solvent Vapors.**

[illegible] aspects of vapor degrease installations and operations shall be approved by

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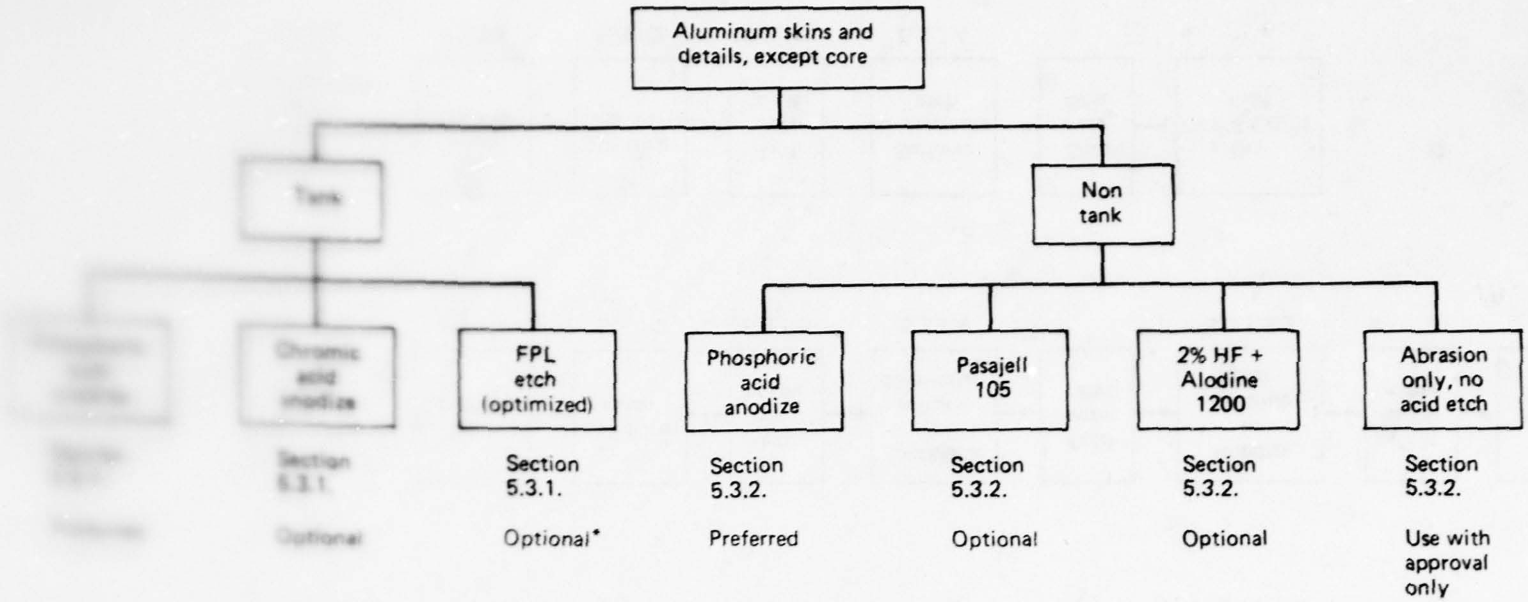
The health and safety aspects of vapor degrease installations and operations shall be approved by industrial hygiene and safety personnel.

Table 5-1.—Surface Preparation Methods



*Preferred for 350° F curing adhesives having nitrile components, e.g., FM 61.

Table 5.2.—Tank Processes, Aluminum Surface Preparation

Process Steps								
Phosphoric acid anodize	Vapor degrease →	Alkaline clean →	Hot water rinse →	Deoxidize in sulfuric-dichromate →	Cold water rinse →	Anodize in phosphoric acid →	Cold water rinse →	Dry 160°F max
Section	5.3.1.1	5.3.1.2	5.3.1.3	5.3.1.4		5.3.1.5.1		
Chromic acid anodize	Vapor degrease →	Alkaline clean →	Hot water rinse →	Deoxidize in sulfuric-dichromate →	Cold water rinse →	Anodize in chromic acid →	Cold water rinse →	Dry 160°F max
Section	5.3.1.1	5.3.1.2	5.3.1.3	5.3.1.4		5.3.1.5.2		
FPL sulfuric acid-sodium dichromate	Vapor degrease →	Alkaline clean →	Hot water rinse →	Sulfuric-dichromate etch →	Cold water rinse →	Dry 130°F ± 10°F max		
Section	5.3.1.1	5.3.1.2	5.3.1.3	5.3.1.4				

General description of procedure:

1. Place parts in racks in a manner that prevents damage and that assures good vapor circulation around all part surfaces and good condensate drainage. Do not allow parts to contact one another.

2. Lower work into the vapor slowly. The rate should not exceed 12 ft/min. For heavy soil the procedure should involve vapor, flush, vapor. Remove insoluble soil by flushing with clean liquid solvent.

   NOTE: Always direct hand-held nozzles downward.

3. Hold the work in the vapor until the solvent stops condensing on the parts. Remove entrapped solvent by tilting the parts in the rack.

4. Slowly remove the work from the degreasing vapor. Allow time for the liquid to drain from the parts. Allow the details to cool.

5. Recycle if necessary.

6. Keep parts clean.

   NOTE: After vapor degreasing and prior to commencing alkaline cleaning, parts should be thoroughly dried to prevent contamination of alkaline cleaner solution with solvent.

5.3.1.2 Alkaline Cleaning

In high-strength applications, particularly when aluminum is to be bonded to itself or to other metals, chemical precleaning is usually mandatory prior to final surface preparation. Consult the engineering authority or the applicable aircraft T.O. to determine which of the particular pretreatments is most appropriate. Recommended alkaline cleaners for aluminum are listed in table 5-3.

CAUTION: Safety Precautions for Handling Caustic Materials Must be Observed During All Operations Involving Alkaline Cleaners. Caustic Cleaners May Spatter When Added to Water.

Preparation of Cleaning Solutions. –Use the following procedures for making up alkaline cleaner solutions. Perform operations listed below:

1. Fill the tank approximately 1/2 full of water.

2. Distribute the required quantity of cleaner uniformly over the water surface slowly and with thorough mixing.

3. Add water to within 2 inches of the operating level.

Table 5-3.—Recommended Alkaline Cleaners

Aluminum cleaner	Restrictions	Control limits, oz / gal	Operating temperature, degrees F
Oakite 61A	1	5 / 8	160 to 190
Turco 2623	1	5 / 8	160 to 175
Wyandotte Altrex B	1 7	6 / 8	135 to 190
Cee Bee A-54	1	6 / 8	135 to 145
Pacific SP-112-LF	1	6 / 8	135 to 145
Pennsalt 2476	1	6 / 8	135 to 145
Turco 4090-14	1	6 / 8	135 to 190
Isoprep 44	2	6 / 8	135 to 145
Northwest LP3651	2	6 / 8	135 to 145
Oakite 61B	2	5 / 8	160 to 190
Oakite 80A	2	6 / 8	135 to 145
Pennsalt A-31	1 3	4 / 8	135 to 185
Turco 4215 and 4215 Additive	1 3	4 / 8 (Turco 4215)	135 to 185
Turco 4215 Special	1 3 4 6 7	4 / 8	135 to 185
Wyandotte Aldet	1 3	4 / 8	135 to 185
Turco 4215	1 5	0.75 / 2.25	145 to 190

Flagnotes in "Restrictions" column)

1 These cleaners are not acceptable when rinse water is reprocessed by deionizing, except as noted in 7.

2 These cleaners are acceptable when rinse water is reprocessed by deionizing.

3 Non-silicated soak cleaners.

4 Use Turco 4215 additive with Turco 4215 to improve ink removal.

5 Non-silicated spray cleaner.

6 Proportions: 1 pint to 1 quart of Turco 4215 additive per 100 gallons of cleaning solution.

7 These cleaners are acceptable when rinse water is reprocessed by deionizing, provided activated charcoal filters are used and the concentration of wetting agents is maintained below 20 ppm after filtering.

4. Heat the solution to the operating temperature. Add water to attain the operating level and mix thoroughly.

Maintenance of Cleaning Solutions. –Use the following procedure to ensure effectiveness of cleaning solutions for aluminum.

1. Maintain the alkaline cleaner solution per specification.

2. Maintain the level of cleaner solutions within two inches of specified operating levels.

3. Skim the solutions as necessary to maintain clean solutions and parts.

4. Dump and make up the immersion alkaline cleaners when the accumulative total additions of cleaner equal 100 percent of the maximum allowable initial charge.

5. The processing solutions and equipment (including air dryers) shall be kept clean at all times. OPERATIONS SHALL BE SUSPENDED AND CORRECTIONS MADE WHEN:

   - Surfaces of parts do not remain water-break-free after withdrawal from the processing solution or the subsequent rinse.
   - A nonremovable smut is formed or particles are deposited on the surface of the part.
   - The solution temperature or composition is outside the control limits.
   - The solution surface has become oily, or has acquired a scum.
   - Parts are pitted or excessively etched.
   - The solution is not at the required operating level.
   - The solution is no longer effective.

6. A laboratory shall analyze the solutions and describe and record additions, purifications, or withdrawals required to make the solution comply with the required control specification.

7. Do not use metal cleaning facilities to clean nonmetals (e.g., plastics, reinforced plastics, masking or stop-off materials, etc).

Cleaning Procedure. –Use the following procedure to clean aluminum parts.

1. Parts shall be relatively free of grease and oil before alkaline cleaning to minimize the contamination in the cleaning tanks and to ensure maximum alkaline cleaning effectiveness.

2. Agitate all cleaning solutions after prolonged standing or after addition of chemicals or water to ensure uniformity of concentration.

3. Completely immerse parts in cleaning solutions or rinse tanks. When possible, agitate cleaning solutions, rinse water, or parts during processing.

4. Parts may be immersion rinsed following alkaline cleaning. Do not immersion rinse parts from alkaline or neutral solutions in tanks used for rinsing parts from acid solutions.

5. Control the temperature of cleaning solutions within ±5° F of those selected and maintain the temperature within the allowable ranges specified.

6. Spray cleaning and spray rinsing require that all parts be of such shape and racked in such a manner that all surfaces are contacted by impinging sprays and are adequately drained.

7. The following are the requirements for parts after alkaline cleaning and rinsing:

   - Parts shall be free of smut and soil including wax, pencil marks, and printing ink except as noted in the following comment.

   - All marking ink shall be removed except on aluminum where the more tenacious residual inks are allowed.

   - Except for part areas containing permitted residual marking inks, parts shall show a water-break-free surface. A water-break-free surface is a surface which maintains a continuous water film for a period of at least 30 seconds after having been spray- or immersion-rinsed in clean water at a temperature below 100° F.

5.3.1.3 Rinsing

In rinsing aluminum parts, observe the following:

1. Whenever possible, rinsing after processing in a solution operated above 160° F should include the use of a water-fog curtain above the processing tank to prevent the solution drying on the part.

2. For spray rinsing, use a flow of 1.5 to 3.0 gallons of water per minute over each square foot of tank opening. Parts shall be so positioned that all surfaces are directly accessible to the spray.

3. Sufficient water shall be flowing into the rinse tank to maintain the contaminants below the following levels:

Process	Restrictions on use of rinse water	Maximum total solids content in water (ppm)
Alkaline cleaning	Must not be used to rinse parts from acid processes.	750
Aluminum etching	Must not be used for any other purpose.	150
Anodizing	Preferred for metal bond only.	100

5.3.1.4 Deoxidizing (FPL Etch)

Deoxidizing involves immersion of the aluminum in an active solution that accomplishes one of the following:

- It replaces the weak residual oxide on the metal surface with a strong oxide layer that is more suitable for bonding.
- It provides a suitable surface for the subsequent anodizing process.

All aluminum alloys require etching prior to adhesive application to obtain a suitable quality bond. The parts are etched by immersion in a sulfuric dichromate solution made of sodium dichromate and sulfuric acid. The solution make-up composition and control is indicated below.

Deoxidizing Process. –Immerse the parts in the sulfuric-dichromate solution for the time indicated for the particular process. Without delay, cold water spray rinse for 5 to 15 minutes. After etching, two rinses are commonly used, the first an ambient temperature water spray rinse followed by an ambient or warm immersion rinse. All chemicals must be thoroughly rinsed immediately from the aluminum surface to ensure good bonding results. The quality of water used in the etch solution and rinses must be controlled as indicated in previous section (Alkaline Cleaning).

Immediately after rinsing, the etched parts should be observed for a water-break-free surface. Such a test does not indicate the presence of materials that absorb water, merely the absence of a greasy surface. If a surface is not water-break-free, the part must be recleaned immediately.

If the parts are not to be subsequently anodized prior to bonding, use the following procedure:

1. Etch for 12 to 15 minutes.
2. Rinse.
3. Dry at $130^{\circ} \pm 10^{\circ}$ F.
4. Protect treated parts from contamination.
5. Prime within 16 hours.

Solution Make-Up and Control. –Crack-extension or peel test panels (see sec. 4.4) shall have been tested prior to processing parts through a new solution and shall be used with each load of parts processed.

The deoxidizer solution shall be made up, replenished, and maintained to the following requirements:

1. Solution make-up compound — Concentration limits

Solution make-up compound	Concentration limits
$Na_2Cr_2O_7$	4.1 to 12.0 oz/gal as $Na_2Cr_2O_7 \cdot 2H_2O$
H_2SO_4 66°BE'	38.5 to 41.5 oz/gal as H_2SO_4
Aluminum*	0.20 oz/gal of dissolved aluminum minimum

2. Operating temperature: 150° to 160° F

3. Metal removal rate: 0.00022 to 0.00034 in./surface/hr

   NOTE: When chemical replenishments to maintain control limits do not maintain the required removal rate, adjust the temperature within the specified limits of item 2. above. A temperature increase of 7.0° F will increase the metal removal rate about 0.0001 in./surface/hr.

5.3.1.5 Anodizing

5.3.1.5.1 *Phosphoric Acid Anodize*

Solution composition and operating temperature is as follows:

1. Maintain the total acid (H^+ ion) concentration equivalent to 13- to 16-oz/gal phosphoric acid (H_3PO_4, primary H^+ ion equivalent).

2. Hydrogen ion (H^+) concentration may be determined by any valid method not subject to interference from the dissolved aluminum alloy.

3. The operating temperature of the anodizing solution should be 67° to 77° F.

4. Fungus that may develop in the anodizing solution may be removed by filtering.

The process flow (see table 5-2) is as follows:

1. Vapor degrease (sec. 5.3.1.1) to remove surface contaminants if required by the condition of the detail or part.

2. Alkaline clean (sec. 5.3.1.2) for at least 10 minutes in an approved alkaline cleaner from table 4-4. Without delay, rinse in hot water (110° F minimum) for 5 minutes (sec. 5.3.1.3).

3. Deoxidize in sulfuric-dichromate solution (sec. 5.3.1.4) for 10- to 15 minutes.

*Aluminum shall be 2024 alloy. This alloy is required because of its particular alloy composition. Old solution shall not be used to make up dissolved aluminum.

4. Without delay, rinse in cold water for 5 minutes.

5. Anodize in the phosphoric acid solution for 20 to 25 minutes at 10 volts ± 1 volt. The part is connected as the anode (+).

6. Without delay, cold water rinse for 10 to 15 minutes.

7. Dry at 160° F maximum.

   NOTE: DO NOT TOUCH the anodized surface prior to priming.

8. Examine for anodic coating after parts are dried (step 7). This will be indicated by an interference color when viewed in daylight or through a polarizing filter, as shown in figure 5-3.

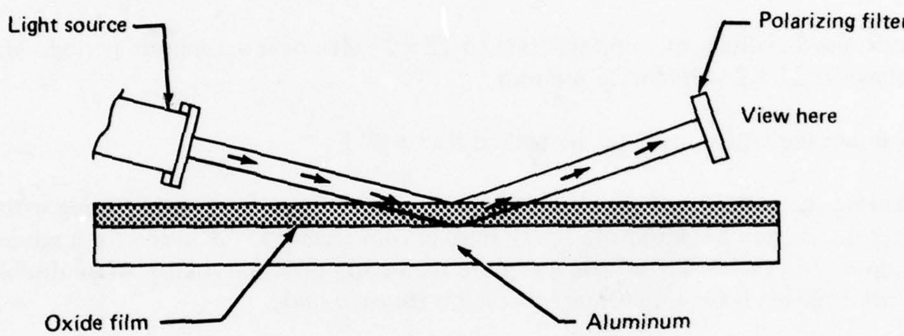


Figure 5-3.—Polarized Light Test—Verification of Anodic Oxide Film

9. If no color is observed, repeat steps 3 through 8.

10. Prime within 72 hours following drying.

5.3.1.5.2 Chromic Acid Anodize

Composition of chromic acid anodize solution is as follows:

1. Initial make-up: 30.0 lb chromic acid per 100 gallons. (3.5% by weight)

2. Control limits:

   a. Total hexavalent chromate (as CrO_3): 4.0 to 13.4 oz/gal (3 to 10% by weight)

   b. Free chromic acid (as CrO_3): 4.0 to 6.7 oz/gal (3 to 5% by weight)

3. Maintain the solution by draw-off and addition of CrO_3, or by ion exchange purification.

The process flow (see table 5-2) is as follows:

1. **Vapor degrease (sec. 5.3.1.1) as required to remove surface contaminants.**

2. Alkaline clean (sec. 5.3.1.2) for 5 to 10 minutes in an approved alkaline cleaner. Without delay, rinse in hot water (110° F minimum) for 5 minutes (sec. 5.3.1.3).

3. Deoxidize in the sulfuric-dichromate solution (sec. 5.3.1.4) for 5 to 10 minutes. Without delay rinse in cold water for 5 minutes.

   CAUTION: Agitate the Anodizing Bath for 10 Minutes Minimum Immediately Prior to Anodizing.

4. Lower the parts into the anodizing bath and apply current with the part as the anode within 5 seconds after immersion. (Time to totally immerse parts shall be 15 seconds.)

5. Raise the dc voltage at a uniform rate to 22 ± 2 volts, over a 5-minute period. Maintain the voltage at 22 ± 2 volts for 25 minutes.

6. Maintain the temperature of the bath at 95° ± 3° F.

7. Remove the current and then raise the parts from the tank and begin rinsing within 2 minutes after the current has stopped. Spray rinse in *cold water (95° F max.)* for a minimum of 5 minutes using water containing not more than 150 ppm total solids. When double counter-current rinsing is used, the time specified is for *each tank*.

   NOTE: It is optional to use individual water-feed, double immersion rinse in lieu of double counter-current rinse.

   CAUTION: DO NOT SEAL the Chromic Acid Anodized Surface for Adhesive Bonding Applications.

8. Dry thoroughly at room temperature to 140° F maximum.

   NOTE: DO NOT TOUCH the anodized surface prior to priming.

9. Prime within 72 hours following drying.

5.3.2 NONTANK PROCESSES

The nontank cleaning methods for aluminum are given in the following sections. An abbreviation of the processing steps is shown in table 5-4. Observe safety procedures and exercise caution in handling the processing solutions. The acid nontank cleaning methods are phosphoric acid nontank anodize, PasaJell 105, and 2% hydrofluoric acid (HF). These are described in the order of preference. A solvent method is given as an alternate. This should only be used with appropriate approval since this procedure gives bonds with greatly reduced durability.

Table 5-4.—Nontank Aluminum Surface Preparation

Section	Process steps					
5.3.2.1	Nontank phosphoric acid *anodize*	Solvent wipe, abrade →	Apply gelled acid, gauze, screen →	Anode (+) substrate, cathode (-) screen 6 volts (dc) 10 minutes →	Remove screen, gauze, rinse →	Dry, check for color
5.3.2.2	PasaJell 105	Solvent wipe, abrade →	Apply PasaJell 105 for 10 to 15 minutes →	Rinse →	Dry	
5.3.2.3	2% HF + chromate conversion coating	Solvent wipe, abrade →	Apply 2% HF, wipe 15 to 30 seconds →	Rinse, apply chromate conversion coating within 15 minutes →	Rinse →	Dry
5.3.2.4	Abrasion, no acid etch	Solvent wipe, abrade →	Remove dust, debris, wipe clean			

NOTE: Prior to the start of processing, be sure undamaged areas, crevices, and fasteners are protected from acid contamination by masking off these areas with suitable tape and plastic film. Protect working bench tops and surrounding areas by placing plastic film (e.g., Mylar) between the part and the bench tops.

Precleaning for the nontank methods is as follows:

1. Solvent wipe the surfaces surrounding the repair area to remove oil, dirt, grease, etc.

2. Remove the organic finish with solvents and mechanical means or with approved strippers. The former is preferred.

   NOTE: Prevent stripper from entering existing bondlines, as stripper may have a deleterious effect on the bond.

5.3.2.1 Phosphoric Acid Nontank Anodize (Preferred Method)

1. Solvent-wipe with MEK, trichlorethane or equivalent.

2. Abrade with nonwoven abrasive such as nylon abrasive pads or equivalent.

3. Dry wipe with clean gauze to remove dust and debris.

4. Apply a uniform coat of gelled 12% phosphoric acid (table 4-4) or PR 50* to aluminum surface.

5. Place 2 or 3 layers of gauze over top of coating; apply another coat of gelled phosphoric acid to completely saturate and wet out the gauze (fig. 5-4).

6. Secure a piece of stainless steel screen over the coating. Apply another coating of the gelled phosphoric acid.

   NOTE: Be sure that the stainless screen DOES NOT CONTACT any part of aluminum surface being anodized.

7. Connect screen as cathode (–) and aluminum as anode (+) as shown in figure 5-5.

   NOTE: Check this set-up before proceeding: *Screen* as *cathode* (–) and *aluminum* as *anode* (+).

8. Apply a dc potential of 6 volts for 10 minutes (4 to 6 volts for 10 to 12 minutes are satisfactory).

   NOTE: A rectifier may be used to supply the voltage and current during anodizing. Current density should be in the range of 1 to 7 amps/ft^2. In an emergency, a fresh or fully charged dry or wet cell battery may be used to anodize small areas.

*Gelled phosphoric acid compound can be purchased from Products Research Corporation or made by adding "cab-o-sil" to 12% phosphoric acid until thickened.

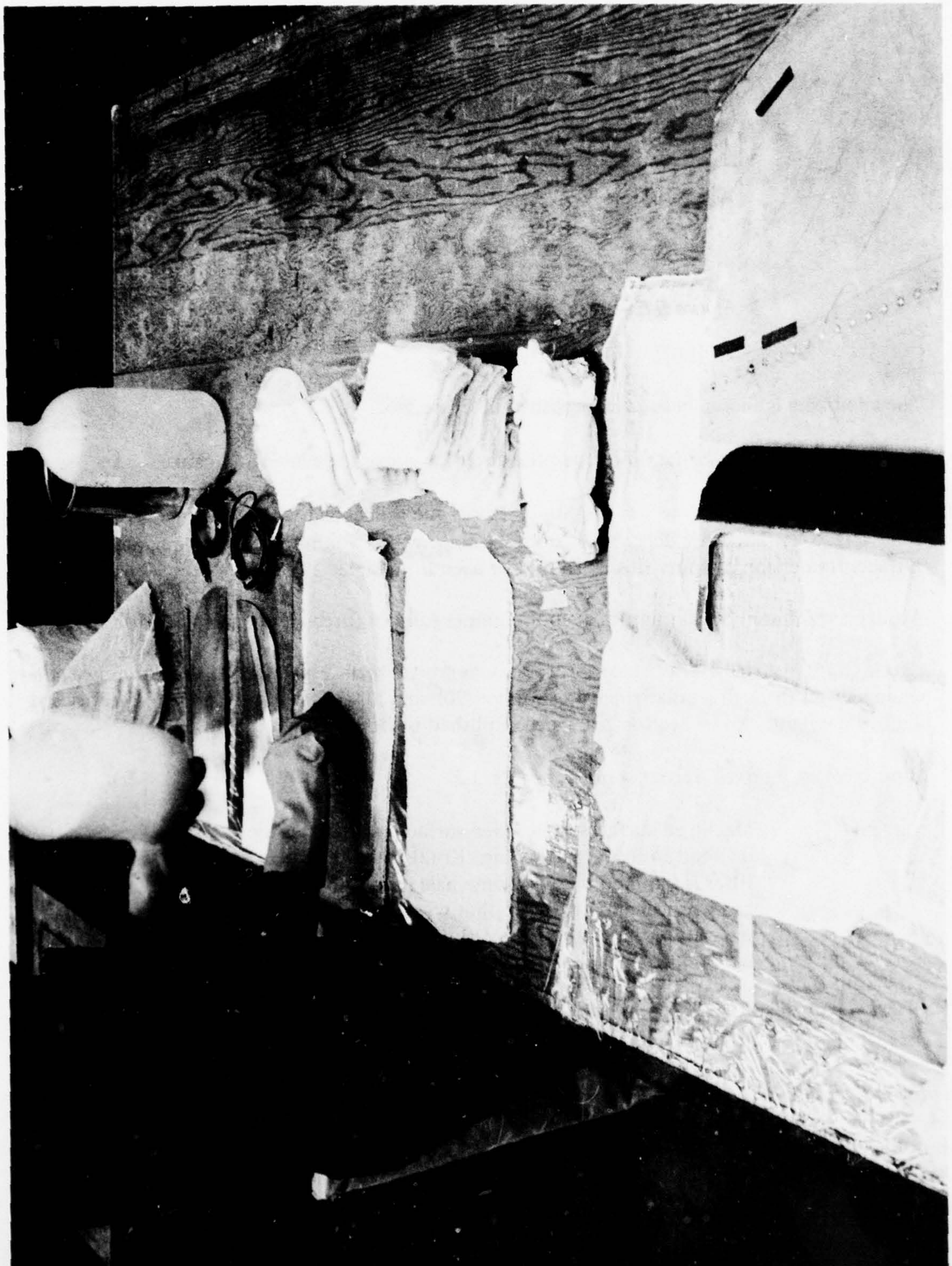
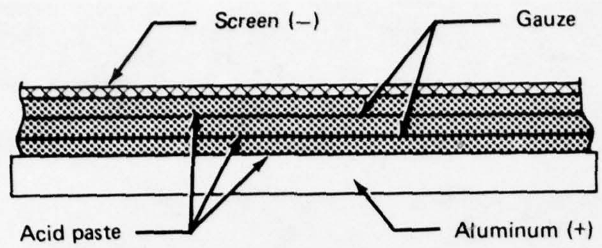


Figure 5-4.—Saturating Gauze Covering Repair Detail with Phosphoric Acid



Anodizing in Process

Figure 5-5.—Anodizing Aluminum Repair Details

The anodizing is shown being accomplished in figure 5-6.

9. At the end of the anodizing time, open the circuit, remove the screen and gauze.

10. Moisten clean gauze with water. Lightly wipe off the gelled acid with moistened gauze without delay (fig. 5-7). The rinse delay time is limited to less than 5 minutes. Do not rub the anodized surface. Immersion or spray rinsing should be used if possible.

11. Air dry a minimum of 30 minutes at room temperature or force-air oven dry at 140° to 160° F.

12. Check quality of prepared surface. A properly anodized surface will show an interference color* when viewed through a polarizing filter rotated 90° at a low angle of incidence to fluorescent light or daylight. An inspection being accomplished is shown in figure 5-8.

13. If no color is observed, repeat steps 4 through 12.

NOTE: Machined surfaces or abraded surfaces sometimes are difficult to inspect for color. Rotation of the polarizing filter is required because some pale shades of yellow or green are so close to white that without a color-change inspection, they might be considered "no color," which would falsely indicate no anodic coating.

CAUTION: DO NOT TOUCH the Dried Anodized Surface. DO NOT Apply Tape to the Surface.

Anodizing Both Surfaces.—In the case of patch doublers or skin details in which both surfaces are to be anodized, a setup as shown in figure 5-9 may be used. In this procedure, both surfaces of the aluminum are coated with the gelled phosphoric acid, covered with acid-coated gauze (2 layers), and then covered with the stainless steel screen as the cathode. It is important to elevate the part slightly to allow gases formed during anodizing to escape from the bottom surface. Trapped gases will result in smut deposits on the surface and poor surface preparation.

*Original color changes to complementary color when polarizing filter is rotated 90°.

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ADHESIVE BONDED AEROSPACE STRUCTURES STANDARDIZED REPAIR HANDBO--ETC(U)
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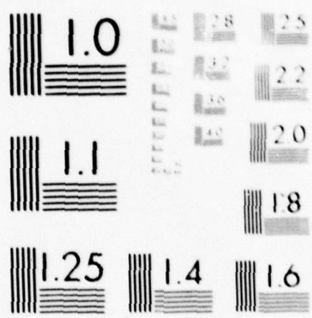
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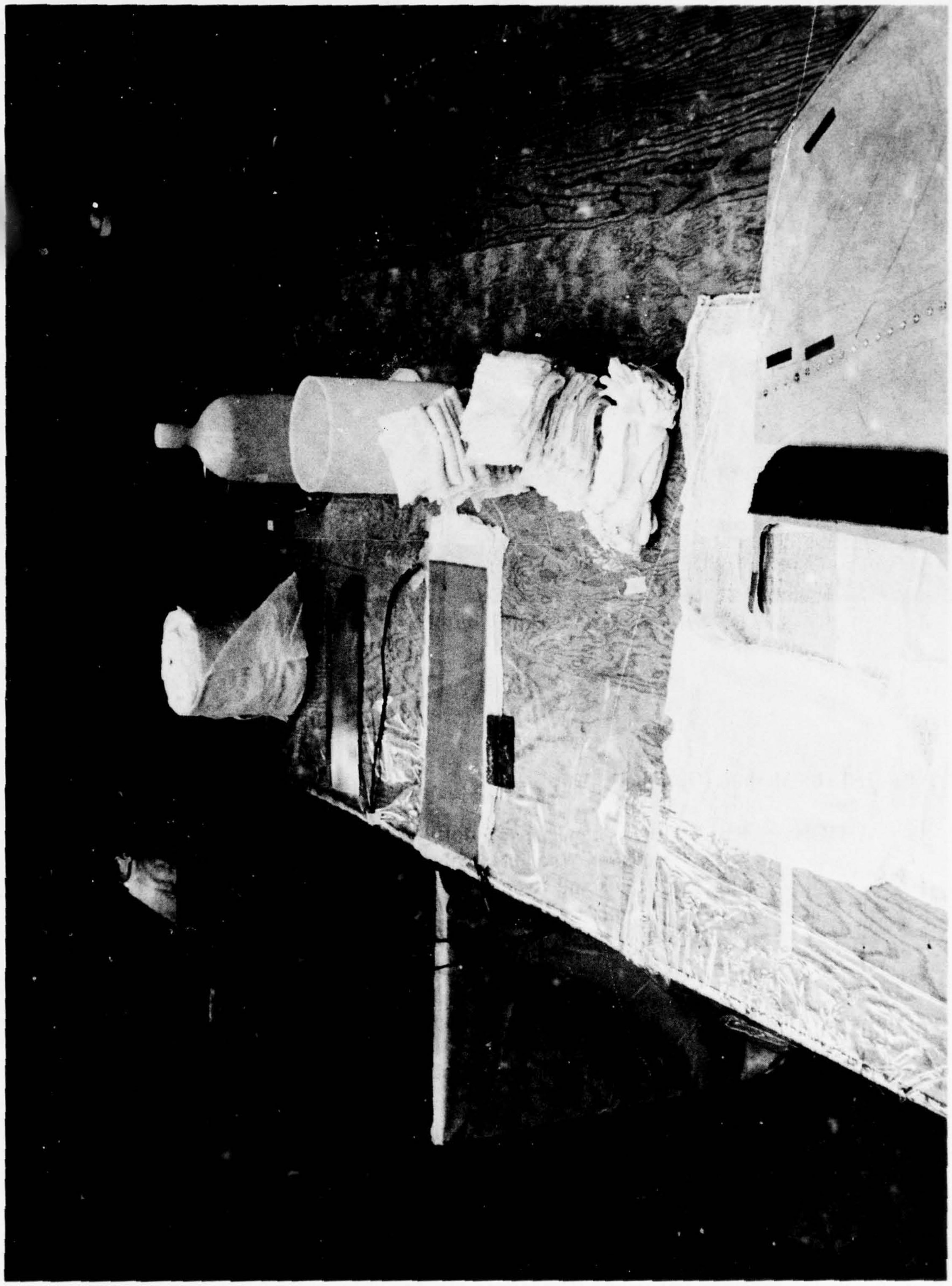


Figure 5-6.–Anodizing in Process

Figure 5-7.–Removing Acid by Gently Wiping With Wet Gauze

5.3.2.2 **PasaJell 105 Method (Optional)**

CAUTION: **PasaJell 105 is Especially Notorious for Causing Severe Corrosion When it Has Been Allowed to Enter Unsealed Joints and Recesses. Mask Those Areas Prior to Use of PasaJell 105. Completely Flush the Areas to Remove all Traces of PasaJell 105 After Using.**

1. Solvent clean with MEK, trichloroethane, or other approved solvent.
2. Abrade with a nylon abrasive pad or 400-grit aluminum oxide abrasive paper.
3. Dry wipe with clean gauze pads.
4. Apply PasaJell 105 to surface with a spatula, brush, or gauze (fig. 5-10).

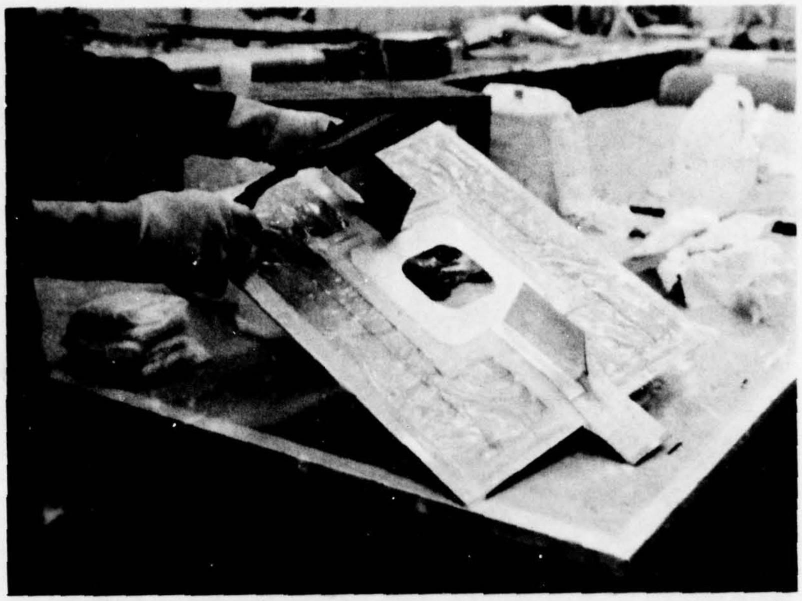


Figure 5-8.—Inspecting the Phosphoric Acid Anodized Surface With a Polarized Filter

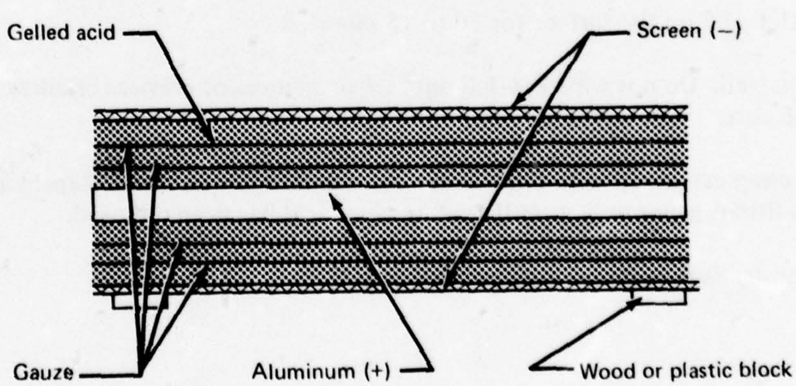
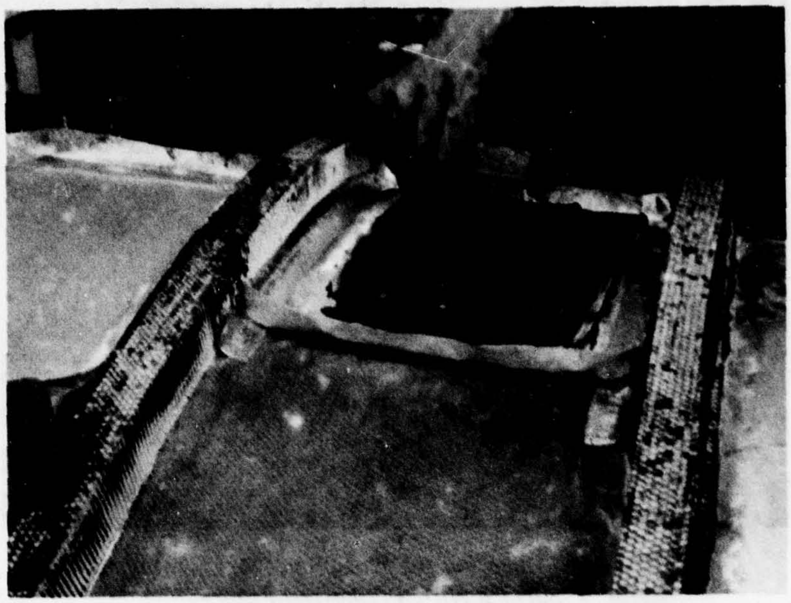


Figure 5-9.—Set Up for Anodizing Both Sides of Aluminum Detail



Aluminum foil tape has been used to make a barrier to contain the acid.

Figure 5-10.—PasaJell 105 Applied to Aluminum Surface for Bonding

WARNING: WEAR RUBBER GLOVES AND GOGGLES WHEN USING PASAJELL. IF SKIN OR EYES COME IN CONTACT WITH ACID, IMMEDIATELY FLUSH WITH WATER.

5. Leave PasaJell 105 on the surface for 10 to 15 minutes.

6. Wipe off PasaJell. Do not wipe PasaJell onto adjacent areas or crevices or allow it to enter honeycomb core.

7. Dampen a clean gauze pad with clean water and wipe the treated area. Repeat as necessary and check with litmus paper to be sure that all trace of acid has been removed.

8. Allow to air dry before applying primer or bonding.

5.3.2.3 Two Percent Hydrofluoric (HF) Acid Method (Optional)

1. Solvent clean with MEK, trichloroethane, or other approved solvent.

2. Abrade the surface thoroughly with nylon abrasive pads (MIL-A-9962 type A) or 400-grit aluminum oxide abrasive paper to remove contaminants.

3. Dry wipe with clean gauze to remove abrasive residue.

4. Moisten (do not saturate) clean gauze with 2% hydrofluoric acid solution. Wipe the abraded area briskly with the pad. Treat this procedure as though the HF were a solvent.

   WARNING: **WEAR RUBBER GLOVES AND GOGGLES WHEN USING HF. IF SKIN CONTACT IS MADE, IMMEDIATELY FLUSH WITH WATER.**

5. After the acid has worked for 15 to 30 seconds, dampen a clean gauze pad with clean water and wipe the acid-treated areas. Do not drag gauze through nontreated areas onto treated areas.

6. Within 15 minutes, apply chromate conversion coating (MIL-C-5541). Instructions for preparation and application of the conversion coating are given in section 4.3.5.

5.3.2.4 Solvent Wipe and Abrade* (Alternate Method)

Do not use this method without appropriate approval. This nontank method is used only on areas internal to the honeycomb panel or in areas where contamination of adjacent structure cannot be prevented if acid were used.

1. Solvent wipe with MEK, trichloroethane, or other approved solvent.

2. Abrade with a nylon abrasive pad (MIL-A-9962 type A) or 400-grit aluminum oxide abrasive paper.

3. Gauze wipe to remove dust or vacuum off dust.

5.4 TITANIUM SURFACE PREPARATION

Titanium surfaces to be repaired shall be prepared with an approved tank method or hand cleaned with PasaJell 107 as follows:

CAUTION: **PasaJell 107 is Notorious for Causing Severe Corrosion When it Has Been Allowed to Enter Unsealed Joints and Recesses. Carefully Mask These Areas Prior to Use of PasaJell 107. Completely Flush the Areas to Remove All Traces of PasaJell 107 After Using.**

***Use with approval only.**

1. Solvent clean with MEK or equivalent solvent using clean cloth.

2. Sand surface with 320-grit nonsilicone wet or dry abrasive paper to remove foreign material and surface finish.

3. Mask off area with lead foil or polyester tape.

NOTE: DO NOT use a chlorinated solvent such as trichloroethane to clean titanium because it may cause hydrogen embrittlement. Note restrictions in MIL-F-5002.

4. Wipe sanded surface with a nonchlorinated solvent. Change cloth frequently until all evidence of sanded dust is removed.

5. Coat the cleaned area with PasaJell 107. Allow PasaJell 107 to remain for 12 to 16 minutes.

6. Rinse coated area with distilled or demineralized water to remove PasaJell. Use blue litmus paper to check for removal of all acid traces.*

7. Dry the treated area at room temperature or at 150° F with a heat lamp.

8. If repair is not completed immediately, protect cleaned surfaces by covering with clean wrapping paper, or prime the area.

5.5 FIBERGLASS SURFACE PREPARATION

This hand clean method for glass-fabric-reinforced surfaces is acceptable for fiberglass repairs.

1. Lightly abrade with 180-grit abrasive paper or equivalent.

2. Remove debris with vacuum.

3. Solvent wipe clean. Wipe surfaces before solvent evaporates.

4. Protect the surface with wax-free paper until the assembly is bonded.

5.6 STAINLESS STEEL SURFACE PREPARATION

Use any approved tank or nontank process for steel surface preparation. The following are suggested guides for 300-series, PH, and 400-series stainless steel surfaces.

5.6.1 300-SERIES STAINLESS STEEL

Sulfuric Acid Pickle

1. Appearance—The surface of 301 and 302 stainless steels shall be uniformly etched and smut removal on the bonding surface shall be generally uniform. Some alloys (316, 321, and 347) are inert to the solutions and may not etch uniformly. These parts will etch heavier in scratches and abraded areas. This shall not be cause for rejection.

*Blue changes to red in presence of acid.

2. Restrictions

   a. Sulfuric Acid Pickle may be used on all 300 series stainless steels for structural and non-structural bonding.

   b. Parts shall be bonded or adhesive primed within 30 days after treatment.

   c. Unprimed parts that have exceeded the storage life shall be processed in accordance with paragraphs 4, 5, and 6 only.

Procedure

1. Degreasing—Oils and grease shall be removed by vapor degreasing or solvent cleaning. Vapor degreasing shall be accomplished using trichloroethane at 188^{o} to 193^{o} F. Solvent cleaning shall be accomplished at room temperature.

2. Alkaline Cleaning—Parts shall be cleaned for 5 to 10 minutes. Cleaning materials shall be used in accordance with the manufacturer's recommendations. Repeat as necessary to remove soils. The alkaline cleaning shall be followed by thorough rinsing.

3. Etching

   a. The parts shall be immersed in a solution of 25 to 35% by volume of sulfuric acid in water.

   b. The parts shall be processed for 4 to 8 minutes at 135^{o} to 145^{o} F.

   c. Timing shall not start until gassing is evident on the parts.

   d. Parts shall be racked with stainless steel wire.

   e. Parts may be immersed in the acid for about one minute, then raised above the acid for approximately five minutes or until the acid starts to react with the steel, after which they are lowered into the acid for the prescribed time.

   f. Parts shall be rinsed or placed in the smut remover immediately after removal from the etch solution.

4. Smut Removal—Excess smut shall be removed by immersing the parts in a solution of sulfuric acid and sodium dichromate. The solution shall be maintained at 22 to 28% (by weight) sulfuric acid and 2 to 3% (by weight) sodium dichromate. Immersion time shall be 1 to 5 minutes at 140^{o} to 160^{o} F. The smut removal shall be followed by a thorough rinse in water at room temperature.

5. Final Rinse—Immerse the parts in the final rinse for 1 to 3 minutes at 140^{o} to 160^{o} F.

6. Dry—Parts shall be dried at room temperature to 160^{o} F.

5.6.2 CARBON STEELS AND 400-SERIES AND PH STAINLESS STEELS

Dry Abrasive Blasting

1. Appearance—The surface shall be completely blasted and there shall be no visible evidence of stains or blasting residue.

   a. Restrictions

      - With the exception of extremely thin sections, Dry Abrasive Blast, may be used to prepare all carbon and pH steels and 400 series stainless steels for bonding.

      - Parts shall be bonded or adhesive primed within four hours after treatment.

Procedure I

1. Degreasing—Oils and grease shall be removed by vapor degreasing or solvent cleaning. Vapor degreasing shall be accomplished using trichloroethane at 188° F to 193° F. Solvent cleaning shall be accomplished at room temperature.

2. Dry Blasting—Blast the surface to be bonded with 80 grit aluminum oxide. Blast uniformly using 50 to 80 psi blasting pressure. Adjust pressure to provide adequate cleaning without warping.

3. Vapor Degrease and Solvent Flush—Suspend the parts in the vapor degreaser and flush all blasted surfaces with clean trichloroethyane. Repeat as necessary to remove blasting residue. Condensed solvent collected in a storage tank on the degreaser may be used.

6.0 REPAIR METHODS, SMALL

6.1 GENERAL

This section provides instructions for making small repairs on bonded aircraft structure. These are typically used to repair damage caused by punctures, dents, scratches, minor edge crushing, or delaminations. These repairs are essentially the "patch type" and are comparable to those in the -3 T.O. manuals.

There are restrictions as to the extent to which this type of repair can be used. These are defined in the -3 T.O. manual for the specific aircraft model. These typically are dependent on the extent of the damage or the additional weight that the repair adds to the component. Violation of these limits may jeopardize the safety of the aircraft or significantly affect the vehicle's flight control characteristics.

The repair methods that are included here are, in general, the best of those that have been reviewed in the various aircraft repair manuals. As such, substitution of these methods can usually be made with either equal or improved properties. Certain practices in making metal bonded structure repairs have been established in this handbook. These are as follows:

1. Minimum use should be made of fiberglass for metal repairs. Fiberglass laminates may be porous and provide for ingress of moisture to the panel interior.

   Fiberglass laminates have low stiffness when compared to metal, and thus a much larger thickness of material is required to pick up equal load with a comparable strain.

   A fiberglass patch, in some cases, may be economically desirable. An example is when there is compound curvature and it is extremely difficult to form a metal patch. If a fiberglass patch is used, it should be well sealed. It should have a minimum of three layers of 181 cloth or equivalent (see sec. 4.5.1, Fiberglass).

2. Moisture leakage of honeycomb panels is a major cause of failure. All panels should have a bonded metal-to-metal seal around the periphery of the repair area of 1 inch minimum width. Patches over holes should have a minimum 1-inch-wide overlap. Panels should be leak-tested after the repair is complete.

3. The use of mechanical fasteners through honeycomb core areas is discouraged. The area around the fastener is difficult to seal and corrosion commonly occurs. If fasteners through honeycomb are required, they should be installed wet, i.e., in holes prefilled with wet sealant. Installation should be as specified in MIL-S-81733.

4. The procedure recommended for repairing delaminations, in general, is to remove and replace the skin locally in the delaminated area. Delaminations are quite commonly the result of improper surface preparation or surface contamination. If the delamination is at an edge, the surfaces have undoubtedly become dirty or at least lightly corroded. Injecting an adhesive into the area without properly preparing the surface is not recommended.

5. It is preferred that a honeycomb core plug be used to replace removed core rather than potting. Potting is heavier and may subsequently cause failure to occur because of the local stiffness. Potting of this type may be used in certain noncritical areas for expediency. This is subject to approval of responsible maintenance personnel.

6. Bare rather than clad aluminum should be used for the bonded repair details because of the superior durability of the bare bonded surface. The exterior of the metal should, subsequently, be protected using approved coating procedures.

7. All detail parts making up a repair assembly should be prefit prior to bonding to ensure proper mating of the bond interfaces.

6.1.1 COMMON ERRORS AND PROBLEMS–CAUSES AND RESULTS

In the repair of bonded structure, there are often repeated errors that result in the majority of difficulties. Some of these are listed below. A special effort should be made to avoid these particular problems.

1. Failure to precisely follow surface preparation instructions and subsequent contamination of the surface prior to bonding–The results are a weak bond and bond surfaces that are easily corroded.

2. Mechanical damage to the surrounding structure during repair–Much of the honeycomb structure is quite fragile and must be protected during the repair procedure. Common damage is caused by clamping parts for machining operations, by bumping with work stands, by dropped tools, or by walking on the honeycomb panel surface.

3. Poor fit-up of details–A mismatch of detail parts can result in inadequate pressure on the bond-line during cure. The result is a porous and weak bond.

4. Use of out-dated materials–The results are weak metal-to-metal bonds and lack of fillets on the honeycomb core.

5. Failure to bring refrigerated materials to room temperature before opening–The material accumulates moisture due to condensation. The result is a weak and porous bond.

6. Poor repair design–The design must provide for an adequate peripheral seal. The use of countersunk fasteners in thin skins presents a common source of skin cracking and corrosive delamination.

6.1.2 FABRICATION OF SMALL HONEYCOMB CORE DETAILS

This section provides a description of cutting procedures that can be used to fabricate core details for the small repairs described throughout section 6.0. These procedures employ the use of portable table top routing equipment and accessories. These can be conveniently used to make transverse cuts through the core such as are required for recesses, tapers, steps, or thickness changes. Vertical cuts can be made with a core-cutting knife.

The equipment and procedures are briefly illustrated here. A more precise identification of the equipment is given in section 8.0. The fabrication of core details for large repairs are given in section 7.0.

Flat Cutting

Doubler recesses, edge steps, or overall reduced thickness may be accomplished with the slicing equipment shown in figure 6-1. The core is fed into the rotation of the cutter. A fence may be set up to guide the edge of the core.

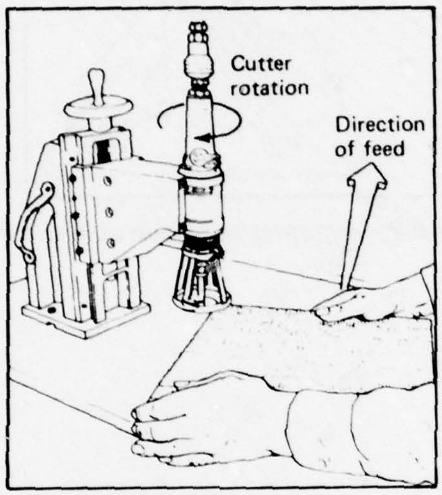


Figure 6-1.—Honeycomb-Core-Slicing Equipment

Angle Cutting

The cutting of angle edges on tapered wedges may be conveniently accomplished with a core-slicing angle plate as shown in figure 6-2. The plate is shown being adjusted to the desired angle.

Honeycomb core being cut along the edge is shown in figure 6-3. The core has been attached to the angle plate with double-backed tape. Other methods may be used where greater attachment strength is required (refer to sec. 7.6.2, Processing of Honeycomb Core).

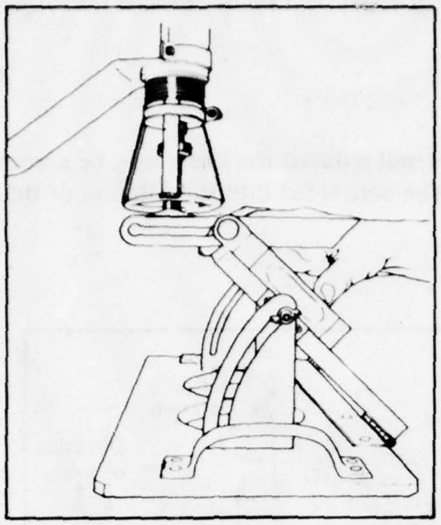


Figure 6-2.–Adjusting the Slope of Angle Plate

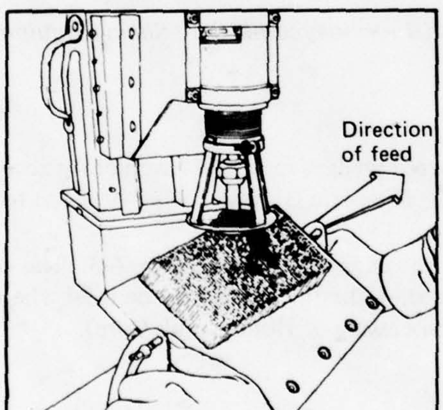
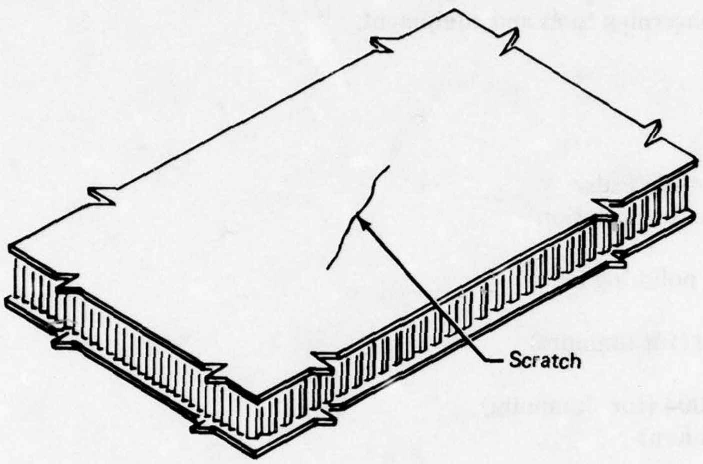


Figure 6-3.–Angle Plate in Use

6.2 REPAIR OF SCRATCHES, SKIN SURFACE

Two types of repair are presented. The first type covers the repair of a light scratch where the scratch depth and length do not significantly degrade the skin strength. For clad aluminum, the scratch does not penetrate through the protective cladding. The repair procedure for this case involves smoothing the surface and restoring the protective metal finish.



A second type of repair is provided for deep or clad-penetrating scratches. This requires the use of a bonded metal patch to restore the skin strength and to more effectively protect the surface.

These methods should not normally be used to repair scratches that penetrate the skin. Repair of this type is accomplished by removing the damaged area. The panel interior is then inspected for moisture and internal corrosion. The area is subsequently repaired by the method used for holes (sec. 6.4 or 6.5). An exception is where the skin-penetrating scratch is repaired immediately and it is known that no moisture has entered the panel interior. In this case, the method for deep scratches (sec. 6.2.2) may be used.

During the repair activity, give special attention to the following items:

WARNINGS: **OBSERVE ALL LOCAL SAFETY PRECAUTIONS AND THOSE DESIGNATED IN SECTION 1.3.**

DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH GENEROUS AMOUNTS OF CLEAN WATER.

WARNING: ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND SOLUTIONS.

6.2.1 LIGHT SCRATCHES

The following lists indicate the types of material and equipment required. Refer to section 4.2 for the specific identification and application instructions for materials. Refer to section 8.0 for more detailed information concerning tools and equipment.

Materials

Caustic soda
Cheesecloth, bleached, 4-ply pads
Chromate conversion coating solution
Cleaner, alkaline
Cloth, rumple, purified polishing fabric
Paint, finish
Solvent, nonchlorinated (for titanium)
Solvent, cleaning
Tape, aluminum foil 0.004 (for aluminum)
Tape, lead foil (for titanium)
Tape, masking, hi-temp
Tape, plastic film, nylon
Water, distilled or demineralized

Tools or Equipment

Abrasive pads, nonwoven, nylon
Abrasive cloth or paper, wet or dry, 180, 220, 320, and 400 grit, aluminum oxide
Brush, acid, 3/8- by 1-inch
Burnishing tool, metal or plastic
Containers, mixing, polyethylene
Emery cloth, 150, 320, and 500 grit, aluminum oxide (for titanium)
Gloves, white cotton fiber
Gloves, rubber or neoprene, surgeons'
Knife, pocket
Micrometer, depth
Rod, mixing, metal or plastic
Safety glasses or shield

Light Scratches in Aluminum

1. Mask the area around the scratch with aluminum foil or polyester tape to prevent further damage and to contain the chemicals or acids used during the repair. Refer to figure 6-4.

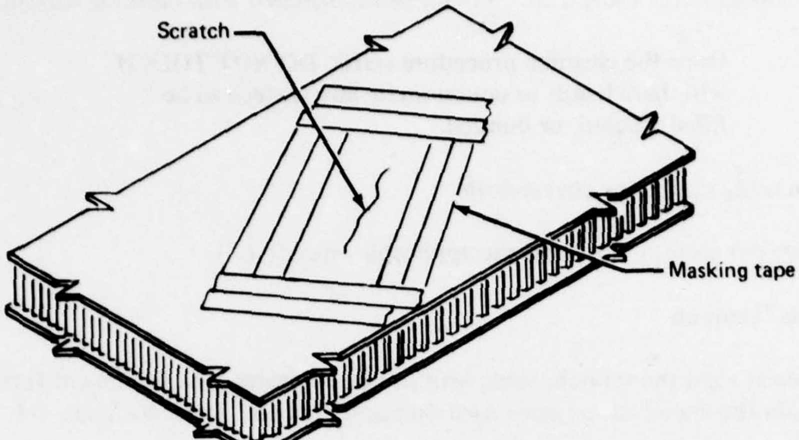


Figure 6-4.—Application of Masking Tape Prior to Surface Cleaning

2. Place a drop of caustic soda, table 4-4, on the clad aluminum skin. If the scratch has penetrated the clad surface, the base material will appear black. If the clad has been penetrated proceed with the method described in section 6.2.2.

CAUTION: DO NOT Allow the Solution to Contact the Previously Cured Adhesive

3. Remove soda with a cheesecloth moistened with alkaline cleaner. Rinse the area thoroughly with water. Check area with red litmus paper to ensure that all caustic has been removed. Rerinse if necessary (red turns blue in presence of alkali).

4. Remove burrs from the skin surface along the scratch using 320- or 400-grit abrasive paper. Take care not to penetrate the cladding during rework.

5. Using 500-grit wet or dry abrasive paper, abrade scratch until scratch is completely removed and a smooth transition exists from skin outer surface to the abraded depth of the smoothed area.

6. Recheck for clad penetration and measure depth and length of the smoothed area. Compare with repair limitations specified in the applicable aircraft -3 T.O. manual. If the removed material exceeds the T.O. limitations, repair per the method in section 6.2.2 should be considered. The presence of excessive scratches may require skin replacement.

7. Clean the smoothed area using a cheesecloth pad moistened with cleaning solvent.

> **NOTE: Once the cleaning procedure starts, DO NOT TOUCH with bare hands or contaminate any surface to be filled, coated, or bonded.**

8. Dry the area using clean, dry cheesecloth.

9. Finish surface per section 4.3.7 and the applicable aircraft T.O.

Light Scratches in Titanium

1. Mask the area around the scratch, using lead foil or polyester tape to prevent further damage and to contain the chemicals or acids used during the repair. Refer to figure 6-4.

2. Using 150-, 320-, and 500-grit aluminum oxide emery cloth, remove any burrs from the skin surface along the scratch area.

   Smooth until scratch is completely removed and a smooth transition exists from the skin outer surface to the sanded depth of the smoothed area.

3. Measure the maximum depth and length of the smoothed area. Check scratch limits for the appropriate skin gage in the applicable aircraft -3 T.O. If limitations are exceeded, the damage may be repaired by the method designated in section 6.2.2. The presence of excessive scratches, however, may require skin replacement.

4. If the damage is within repairable limits for light scratches, clean smoothed area using cheesecloth moistened with nonchlorinated solvent.

> **NOTE: Once the cleaning procedure starts, DO NOT touch with bare hands or contaminate any surface to be filled, coated, or bonded.**

5. Dry area using clean dry cheesecloth.

6. Finish surface per section 4.3.7 and applicable aircraft T.O.

6.2.2 DEEP SCRATCHES, ALUMINUM AND TITANIUM

The following lists indicate the types of material and equipment that are required for the repair of deep scratches. Refer to section 4.2 and 5.0 for the specific identification, preparation, and application instructions for the materials. Refer to section 8.0 for more detailed information concerning tools and equipment.

Materials

Adhesive, film
Aluminum sheet
Aerodynamic smoother
Cheesecloth, bleached, 4-ply pads
Chromate conversion coating
Cleaner, alkaline
Caustic soda
Cloth, bleeder
Cloth, fiberglass, 181 fabric
Cloth, rumple, purified polishing fabric
Film, release
Film, vacuum bagging
Paint, finish
Primer, adhesive
Primer, aerodynamic smoother
Putty, vacuum seal
Solution, surface preparation
Solvent, cleaning
Tape, aluminum foil 0.004 (for aluminum)
Tape, lead foil (for titanium)
Tape, masking, hi-temp
Tape, plastic film, nylon
Titanium, sheet
Water, distilled or demineralized

Tools or Equipment

Abrasive pads, nonwoven, nylon,
Abrasive cloth or paper, wet or dry, 180, 220, 320, and 400-grit aluminum oxide
Asperator, vacuum
Air supply, 90 to 100 psi (w/pressure regulator, filter, and oil trap)
Blanket, insulation
Blanket, heater, electric
Brush, acid, 3/8- by 1-inch
Brush, paint, short bristle, 1-1/2-inch
Cloth, emery, 150, 320, and 400 grit, aluminum oxide (for titanium)
Containers, mixing, polyethylene
Controller, electrical, Variac or power stat, adjustable, ac
Drills, assorted sizes
Drill motor, pneumatic or electric (explosionproof in fuel areas)
Fillet gun, sealant
Fly cutter
Gage, air pressure, 100 psi
Gage, vacuum, 32 in. Hg

Gloves, heat insulating
Gloves, white cotton fiber
Gloves, rubber or neoprene, surgeons'
Hose, vacuum w/fittings
Knife, pocket
Micrometer, depth
Micro stop, drill
Pen, ink marking
Power supply, 115 volt, 60 cycle, ac
Pressure plate, 0.125- and 0.250-inch aluminum
Probes, vacuum, connector
Pyrometer, 0^{o} to 400^{o} F, automatic recording
Router motor, pneumatic or electric (explosionproof for fuel areas)
Router templates
Safety glasses or shield
Saw, reciprocating, pneumatic or electric (explosionproof for fuel areas)
Scribe
Tin snips, metal cutting
Vacuum source
Wire, thermocouple, type J or equivalent

Repair Procedure for Deep Scratches

1. Locate center of scratch and with an ink pencil mark coordinate lines parallel and transverse to the scratch to index the scratch center (see fig. 6-5).

2. Mask the area around the scratch to contain chemicals and to prevent further damage during rework. Use aluminum foil or polyester tape for aluminum and lead foil or polyester tape for titanium.

3. Remove burrs and blend with adjacent surface using 220- to 320-grit abrasive cloth or nylon abrasive pads per MIL-A-9962 type A for aluminum and fine aluminum oxide emery cloth for titanium.

4. Determine the depth and size of the smoothed area.

5. Determine the size of the metal overlay patch as shown in figure 6-6. The thickness of the patch should be equal to or slightly greater than the smoothed area depth. It should be of the same alloy as the skin.

6. Prepare the metal overlay patch. Add coordinate lines.

7. Prepare the surface of the repair area and one surface (unbeveled side) of the overlay patch for bonding per instructions outlined in section 5.3. Observe special notes to keep the cleaned surface free from contamination.

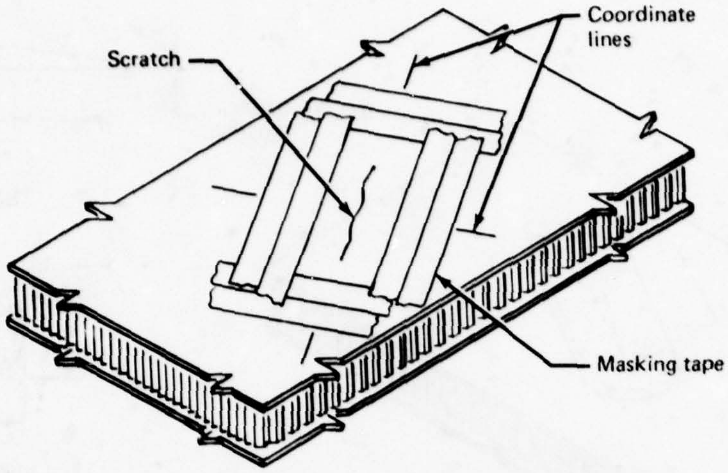


Figure 6-5.—Marked Coordinate Lines for Centering Patch Plate Over Scratch

NOTE: DO NOT allow the surface preparation solutions to contact the previously cured adhesive.

Once the cleaning procedure starts, DO NOT TOUCH with bare hands or contaminate any surface to be filled, coated, or bonded.

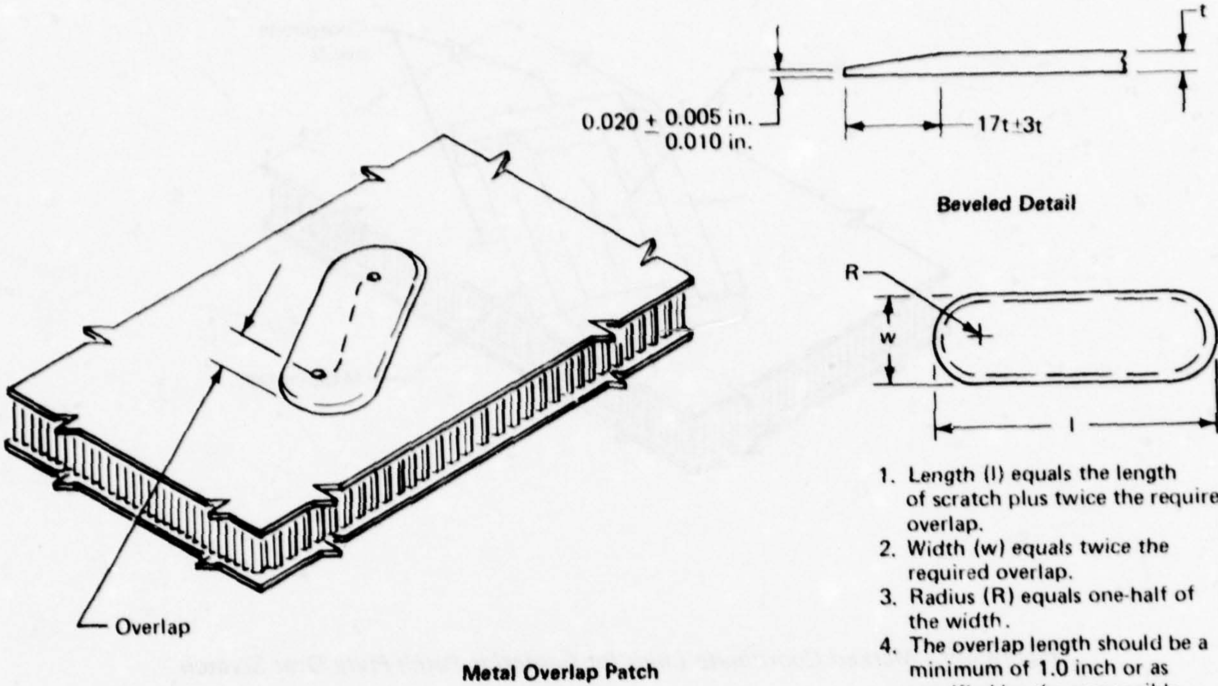
If the repair is not continued within 2 hours following cleaning, the cleaned areas shall be covered using clean Kraft paper.

8. Select the appropriate primer and adhesive per instructions in section 4.2.1.

   NOTE: White cotton lintless gloves shall be worn when handling the adhesive.

9. Apply primer to the repair area and cleaned side of the overlay patch. Cure the primer per instructions in section 4.3.1.

10. Cut a piece of adhesive film the same size as the metal overlay patch.



1. Length (l) equals the length of scratch plus twice the required overlap.
2. Width (w) equals twice the required overlap.
3. Radius (R) equals one-half of the width.
4. The overlap length should be a minimum of 1.0 inch or as specified by the responsible engineering authority.

Figure 6-6.—Detail of Beveled Metal Overlap Patch for Repair of Deep Scratches

11. Center the adhesive film over the repair area.

12. Place the metal overlay patch over the adhesive film. Secure in place with nylon or polyester tape.

13. Locate thermocouples around the patch. Secure in place with nylon or polyester tape.

14. Remove the protective masking tape.

15. Prepare the layup for bonding in accordance with section 7.11.

16. Bond the overlay patch per requirements for the selected adhesive system in table 4-3.

17. Remove the bonding equipment.

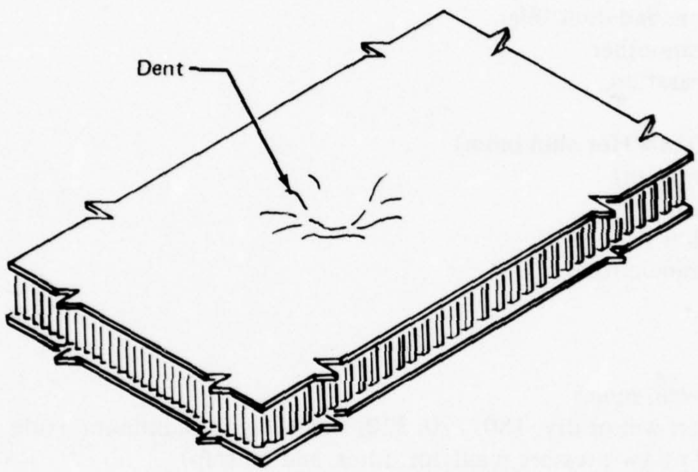
WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT PARTS OR EQUIPMENT.

18. Apply aerodynamic smoother around the patch plate per section 4.3.6.

19 Finish the external surface per section 4.3.7 and the applicable aircraft T.O.

6.3 DENTS, SKIN SURFACE

These methods apply to dents that do not contain cracks. Dents containing cracks should be repaired by methods used for holes (see sec. 6.4 or 6.5). Other limitations apply that are designated in the specific aircraft model's T.O. manual. It is cautioned that dents that are not covered by T.O. repair requirements may still significantly reduce structural capability. Additional guidance concerning criteria for dent repair should be obtained from the responsible engineering authority.



During the repair activity, give special attention to the following items:

WARNING: **OBSERVE LOCAL SAFETY PRECAUTIONS AND THOSE DESIGNATED IN SECTION 1.3.**

DO NOT ALLOW CONCENTRATED MIXES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH GENEROUS AMOUNT OF CLEAN WATER.

ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND SOLUTIONS.

The following lists indicate the types of materials and equipment required. Refer to section 4.2 for specific information and application instructions for materials. Refer to section 8.0 for more detailed information concerning tools and equipment.

Materials

Aerodynamic smoother
Cheesecloth, bleached, 4-ply pads
Chromate conversion coating
Cleaner, alkaline
Cloth, rumple, purified polishing fabric
Paint, finish
Paper, Kraft, wrapping, wax-free
Potting compound, core and dent filler
Primer, aerodynamic smoother
Solution, surface preparation
Solvent, cleaning
Tape, aluminum foil 0.004 (for aluminum)
Tape, lead foil (for titanium)
Tape, masking, hi-temp
Tape, plastic film, nylon
Water, distilled or demineralized

Tools or Equipment

Abrasive pads, nonwoven, nylon
Abrasive cloth or paper, wet or dry, 180, 220, 320, and 400 grit, aluminum oxide
Air supply, 90 to 100 psi (w/pressure regulator, filter, and oil trap)
Brush, acid, 3/8- by 1-inch
Brush, paint, short bristle, 1-1/2-inch
Containers, mixing, polyethylene
Emery cloth, 150, 320, and 400 grit, aluminum oxide (for titanium)
Fillet gun, sealant
Gloves, heat insulating
Gloves, white cotton fiber
Gloves, rubber or neoprene, surgeons'
Heat lamps, 200 to 350 watt (explosionproof)
Knife, putty
Knife, pocket
Micrometer, depth
Pen, ink marking
Power supply, 115 volt, 60 cycle, ac
Pyrometer, 0^{o} to 400^{o} F, automatic recording
Safety glasses or shield
Spatula, wood or metal
Vacuum cleaner, industrial or hand-type
Wire, thermocouple, type J or equivalent

6.3.1 REPAIR PROCEDURES FOR DENTS

1. Locate the center of the damaged area and with an ink pen mark coordinate lines which, if extended, would pass through the center of the damaged area.

2. Mask off an area approximately 3 inches beyond the damaged area to prevent further damage and to contain any chemical or acid used during the repair. Use aluminum foil or polyester tape for aluminum skins or lead foil or polyester tape for titanium skins.

3. Using 220-, 320-, or 400-grit abrasive paper or nylon abrasive pads for aluminum or 320- or 400-grit aluminum oxide emery cloth for titanium, abrade the dented area lightly until a high luster is obtained.

4. Clean the dented area per instructions for bonding in section 5.3.

   CAUTION: **Once the Cleaning Procedure Starts, DO NOT TOUCH With Bare Hands or Contaminate Any Surface to Be Filled, Coated, or Bonded.**

   DO NOT Allow Solution to Enter The Assembly or Contact the Previously Cured Adhesive.

5. Apply primer if required, on the prepared surface, per section 4.3.1.

   CAUTION: **Primer Should Be Applied Within 2 Hours After the Dented Area is Cleaned.**

   Primer Must Be Smoothed Prior to Cure

6. Apply aerodynamic smoother to dent (per sec. 4.3.6) to return area to skin contour.

7. Remove protective tape from area around repair.

8. Locate thermocouples adjacent to the repair. Secure in place with nylon or polyester tape.

9. Cure aerodynamic smoother per instructions in table 4-3 or manufacturer's instructions.

10. Sand smoothed area with 320- or 400-grit abrasive cloth or fine emery cloth to improve surface contour and smoothness (refer to step 3 above).

11. Finish external surface per section 4.3.7 and applicable aircraft T.O.

6.4 HOLE IN ONE SANDWICH SKIN OR SKIN DELAMINATION, NO CORE DAMAGE

This procedure applies to holes in one skin of a honeycomb sandwich where there is no core damage (see fig. 6-7). The holes may typically be caused by gouges or cracks.

This procedure should also be used for the repair of delaminations. Delaminations should not be repaired simply by injecting adhesive since the delaminated surface has undoubtedly been contaminated and must be cleaned prior to bonding.

During the repair activity, give special attention to the following items:

WARNING: OBSERVE ALL LOCAL SAFETY PRECAUTIONS AND THOSE DESIGNATED IN SECTION 1.3.

DO NOT ALLOW CONCENTRATED MIXES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH A GENEROUS AMOUNT OF CLEAN WATER.

ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND SOLUTIONS.

IF THE REPAIR IS IN A FUEL TANK AREA THE FUEL TANK PRESSURE SHALL BE RELIEVED PRIOR TO STARTING THE REPAIR. OBSERVE OTHER PRECAUTIONARY PROCEDURES AS DESIGNATED BY THE SAFETY OFFICER.

The following lists indicate the types of materials and equipment required. Refer to section 4.2 for specific information and application instructions for materials. Refer to section 8.0 for more detailed information concerning tools and equipment. Refer to section 10.0 for NDI requirements.

Materials

Adhesive, film
Aluminum sheet
Cheesecloth, bleached, 4-ply pads
Chromate conversion coating
Cleaner, alkaline
Cloth, bleeder
Cloth, rumple, purified polishing fabric
Film, release
Film, vacuum bagging

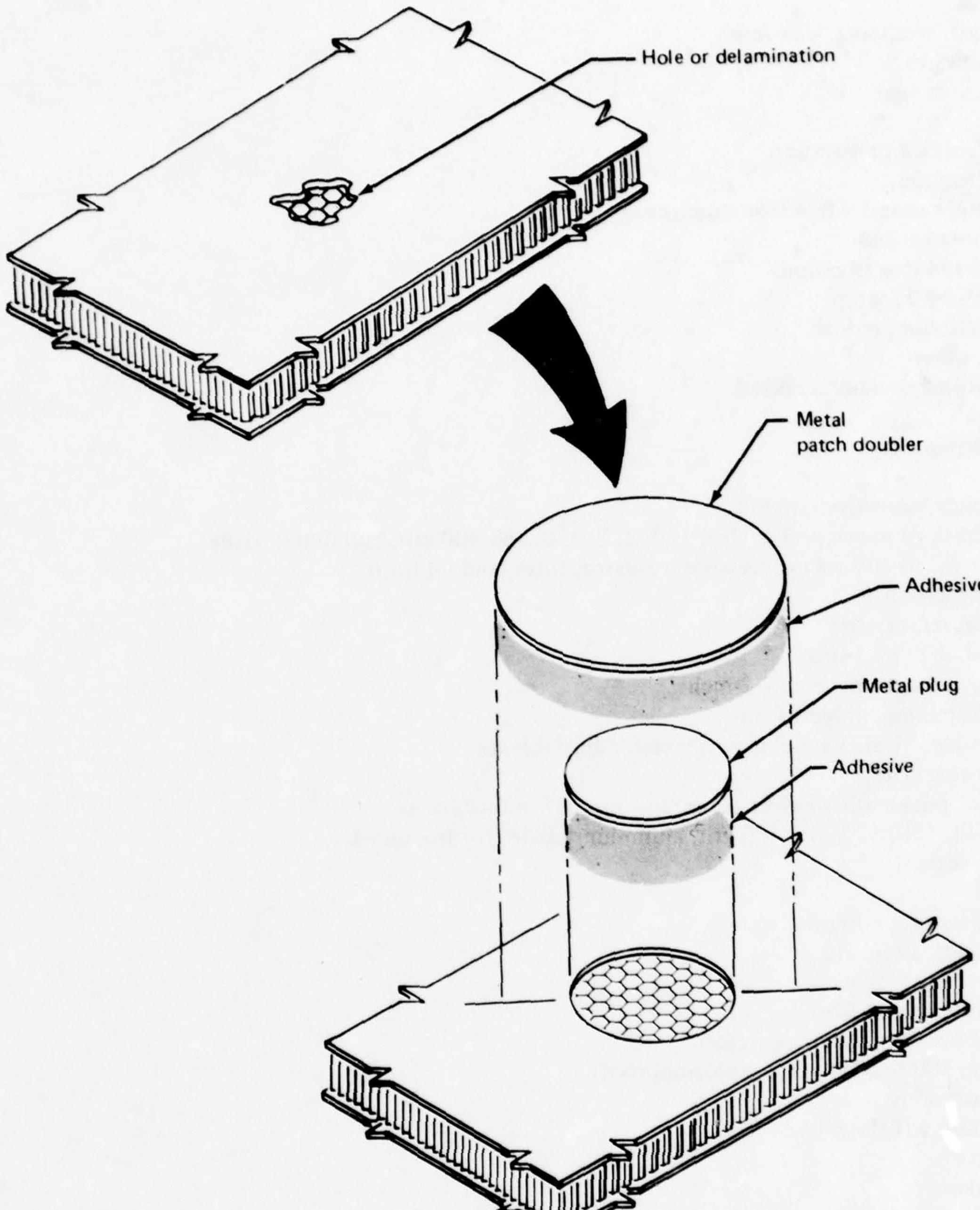


Figure 6-7.–Schematic of Repair of Surface Puncture or Delamination

Paint, finish
Paper, Kraft, wrapping, wax-free
Primer, adhesive
Putty, vacuum seal
Sealant
Solution, surface preparation
Solvent, cleaning
Tape, aluminum foil 0.004 (for aluminum)
Tape, double-backed
Tape, lead foil (for titanium)
Tape, masking, hi-temp
Tape, plastic film, nylon
Titanium, sheet
Water, distilled or demineralized

Tools or Equipment

Abrasive pads, nonwoven, nylon
Abrasive cloth or paper, wet or dry, 180, 220, 320, and 400 grit, aluminum oxide
Air supply, 90 to 100 psi (w/pressure regulator, filter, and oil trap)
Blanket, insulation
Blanket, heater, electric
Brush, acid, 3/8- by 1-inch
Brush, paint, short bristle, 1-1/2-inch
Containers, mixing, polyethylene
Controller, electrical, Variac or power stat, adjustable, ac
Drills, assorted sizes
Drill motor, pneumatic or electric (explosionproof in fuel areas)
Emery cloth, 150, 320, and 400 grit, aluminum oxide (for titanium)
Fillet gun, sealant
Fly cutter
Gage, air pressure, 100 psi
Gage, vacuum, 32 in. Hg
Gloves, heat insulating
Gloves, white cotton fiber
Gloves, rubber or neoprene, surgeons'
Heat lamps, 200 to 350 watt (explosionproof)
Hole saw assembly
Hose, vacuum w/fittings
Knife, putty
Knife, pocket
Micro stop, drill
Pen, ink marking
Power supply, 115 volt, 60 cycle, ac
Probes, vacuum, connector
Pyrometer, 0^{o} to 400^{o} F, automatic recording

Router bits, assorted sizes
Router motor, pneumatic or electric (explosionproof for fuel areas)
Router templates
Safety glasses or shield
Spatula, wood or metal
Tin snips, metal cutting
Vacuum cleaner, industrial or hand-type
Vacuum source
Wire, thermocouple, type J or equivalent

6.4.1 REPAIR PROCEDURES FOR A HOLE IN ONE SKIN OR DELAMINATION, NO CORE DAMAGE

Use the following repair procedures:

1. Locate the center of the damaged area and with an ink pencil, draw coordinates which, if extended, would pass through the center of the damaged area (see fig. 6-8).

2. Mask the area around the repair area to prevent further damage during rework. Use aluminum foil or polyester tape for aluminum and lead foil or polyester tape for titanium.

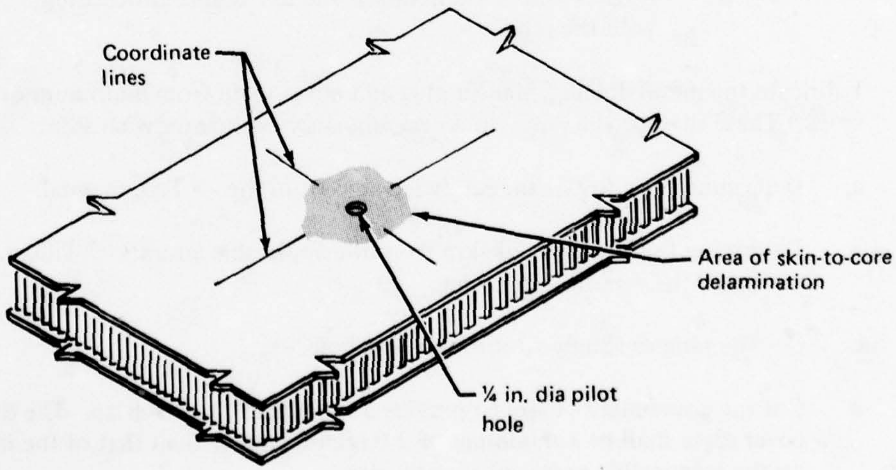


Figure 6-8.—Marked Coordinate Lines for Centering Patch Over Hole or Delamination

3. Remove the skin a minimum of 0.25 inch beyond the edge of the damaged or delaminated area. Use a carbide-tipped cutter for titanium, mild steel for aluminum. Note that a circular cut is usually the easiest to make where it is applicable.

> **CAUTION: DO NOT Cut Through the Adhesive Layer Between the Skin and Core.**

4. Remove the damaged portion of the skin or the portion of the skin covering the delaminated area. Cooling with dry ice may facilitate removing the circular piece. Be careful not to damage the core.

5. If the edge of the skin patch comes off quite easily, indicating a poor bond, the hole size should be enlarged. This can be done by reattaching the skin patch with double-backed tape and selecting a larger diameter cutter. The maximum hole size limits are stipulated in the applicable aircraft –3 T.O. manual. For larger areas, the entire skin should be removed and replaced per section 7.0.

> NOTE: After the skin is removed, and if there is core damage, make the repair per section 6.6. If the core is not damaged, continue with this procedure.
>
> Inspect for moisture and corrosion. If moisture or corrosion is present, its extent must be determined and it must be removed. If the repair area is contaminated with fuel or hydraulic fluid, use MEK or another suitable solvent, and a brush to clean. Be sure the area is free from contamination and dry before proceeding with the repair.

6. Fabricate the metal details. Make a plug and cover plate from aluminum or titanium sheet stock. These shall be the same thickness and alloy as the sandwich skin.

   a. Determine the alloy of the sandwich skin from the –3 T.O. manual.

   b. Determine the thickness of skin from the applicable aircraft –3 T.O. manual or by "miking" the removed skin plug.

   c. Cut the plug to snugly fit into the skin hole.

   d. Cut the cover plate of size to provide a sufficient bond overlap. The diameter of the cover plate shall be a minimum of 2.0 inches greater than that of the hole or as specified by the responsible engineering authority.

   e. If the aluminum or titanium exceeds 0.025 inch in thickness, the cover plate edge shall be beveled per figure 6-9.

   f. Using an ink pencil, draw coordinate lines through the center of tapered side of cover plate (fig. 6-10).

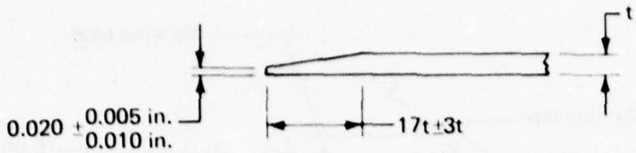


Figure 6-9.–Beveled Edge of Patch Plate

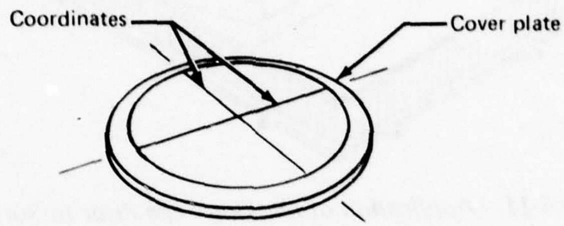


Figure 6-10.–Beveled Patch Plate With Coordinate Lines

7. Mask the hole in the skin with tape to prevent contamination during cleaning of the skin surface. Use aluminum foil or polyester tape on aluminum skins and lead foil or polyester tape on titanium skins. When covering the core, overlap the skin surface 0.060 ± 0.020 inches. See figure 6-11. Similarly mask around the cutout, leaving the area clear that will be cleaned for bonding the patch plate.

8. Remove any organic finish from the surface of the repair area using 180-grit abrasive cloth. Secondly, sand the area to a satin finish with a 400-grit abrasive cloth or fine emery cloth. Nylon abrasive pads may be used to polish the surface of the aluminum.

9. Prepare the surface of the core and the skin area to be bonded per instructions outlined in section 5.0. Do not remove the coordinate lines.

CAUTION: **Once the Cleaning Procedure Starts, DO NOT TOUCH With Bare Hands or Contaminate Any Surface to Be Filled, Coated, or Bonded.**

DO NOT ALLOW the Solutions to Enter the Assembly or Contact the Previously Cured Adhesive.

10. Clean both sides of the metal plug and one side of the cover plate (opposite the bevel). Again observe special notes regarding touching the cleaned surfaces.

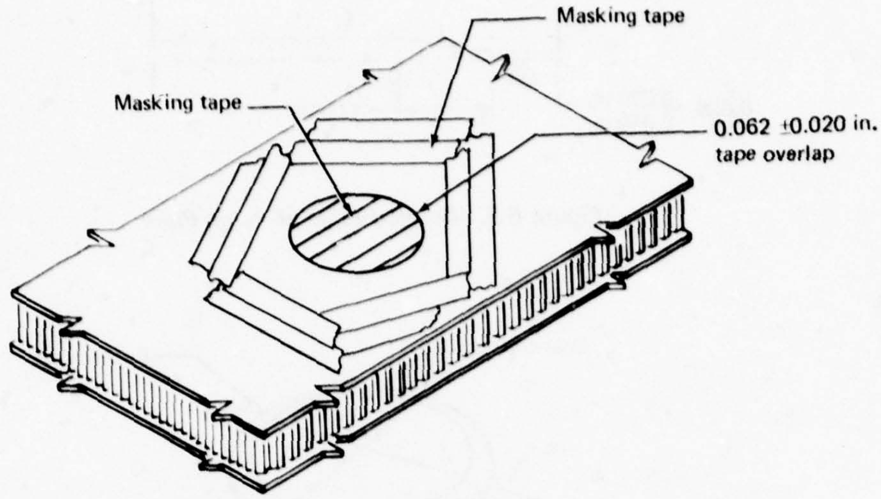


Figure 6-11.—Application of Masking Tape Prior to Surface Cleaning

NOTE: If the repair is not continued within 2 hours following cleaning, the cleaned area shall be covered with clean wax-free Kraft paper.

11. Apply primer and adhesive. Position the skin plug and cover plate for bonding.

    a. Apply applicable primer to skin area, plug and cover plate per section 4.3.1. Cure as required.

    NOTE: White cotton, lintless gloves shall be worn when handling adhesive.

    b. Remove the required adhesive from storage and observe precautionary note (sec. 1.2.5). Do not touch the adhesive with bare hands.

    c. Cut two adhesive disks, the same diameter as the cover plate and plug. See sections 4.2 and 4.3.

    d. Place exposed side of the larger adhesive disk on the clean side of the cover plate. Place the other disk on either side of the plug.

    e. Place the plug in the cutout with the adhesive side down. Align the cover plate coordinates with repair area coordinates with the adhesive side down. Place the cover plate over the plug and secure in position with nylon or polyester tape (fig. 6-12).

12. Remove the protective masking tape surrounding the repair area.

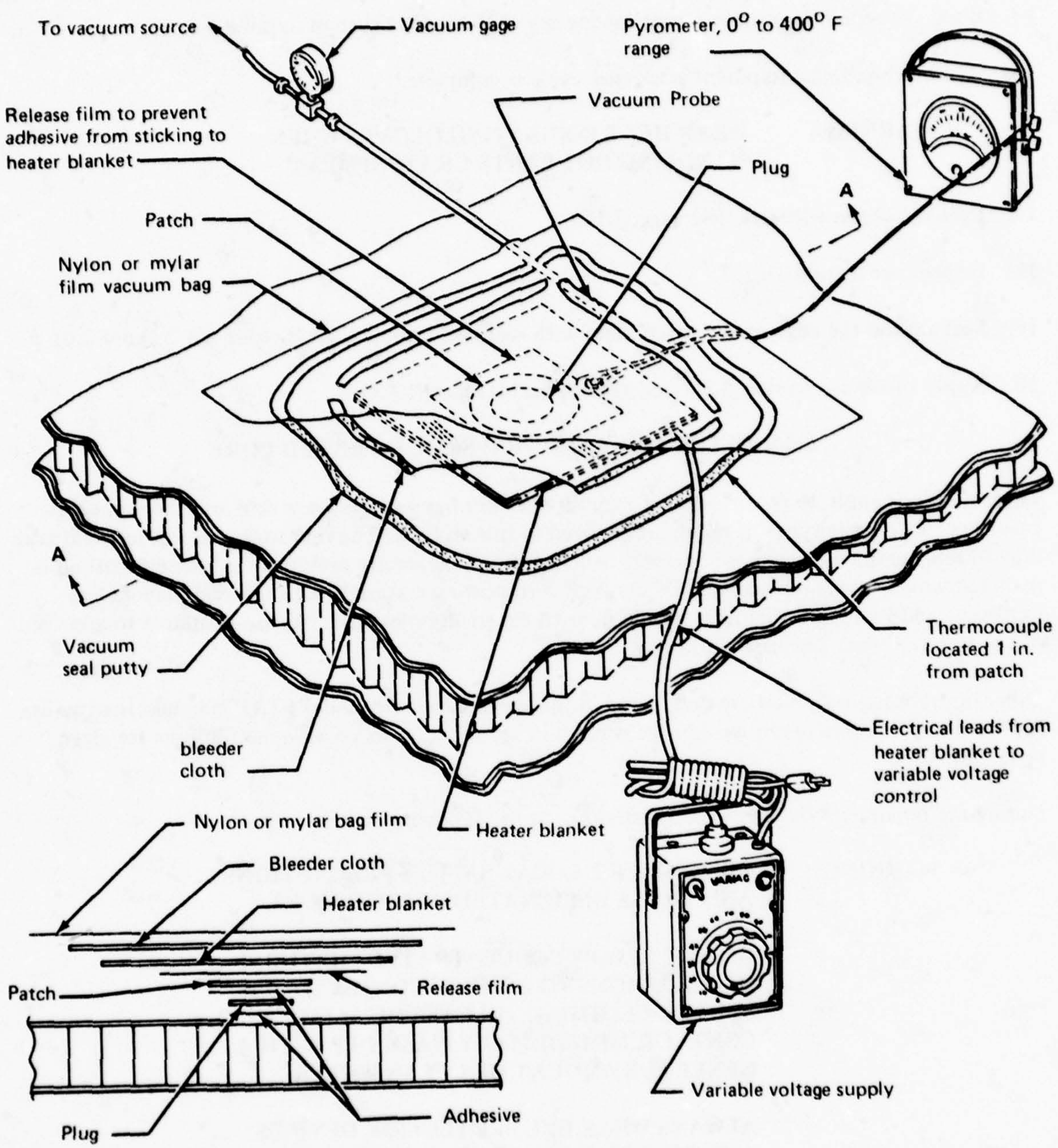


Figure 6-12.–Finished Layup Ready for Adhesive Cure

13. Locate thermocouples around the repair area.

14. Prepare the repair for bonding in accordance with section (sec. 7.12).

15. Bond the repair per requirements for the selected adhesive system in table 4-3.

16. Remove bonding equipment after cure cycle is complete.

WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT PARTS OR EQUIPMENT.

17. Remove excess adhesive flash (sec. 7.12).

18. Inspect per section 10.1.7.

19. Seal around the edge of the patch plate with sealing compound (refer to sec. 4.2 and 4.3.6).

20. Apply finish per section 4.3.7 and the applicable aircraft T.O.

6.5 HOLE IN ONE SANDWICH SKIN, DAMAGED CORE

These methods apply to repair where a puncture or dent has damaged one skin and the immediate core area. Two basic types of repair are covered in this section. The first utilizes a replacement core plug to replace the damaged honeycomb. This method is generally preferred. A second method is included which covers replacement of the core with potting material. This method may be less expensive and more expedient. It should be used for small holes only. Its use is subject to approval of the responsible engineering authority.

Other limitations apply that are designated in the specific aircraft model's T.O. manual. Instruction for the repair of more extensive damage is given in section 7.0. Inspection instructions are given in section 10.0.

During the repair activity, give special attention to the following items:

WARNING: OBSERVE ALL LOCAL SAFETY PRECAUTIONS AND THOSE DESIGNATED IN SECTION 1.3.

DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH A GENEROUS AMOUNT OF CLEAN WATER.

ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND SOLUTIONS.

WARNING: **IF THE REPAIR IS IN A FUEL TANK AREA THE FUEL TANK PRESSURE SHALL BE RELIEVED PRIOR TO STARTING THE REPAIR. OBSERVE OTHER PRECAUTIONARY PROCEDURES AS DESIGNATED BY THE SAFETY OFFICER.**

The following lists indicate the types of materials and equipment required. Refer to section 4.2 for specific information and application instructions for materials. Refer to section 8.0 for more detailed information concerning tools and equipment.

Materials

Adhesive, core splice foam
Adhesive, film
Adhesive, paste
Aluminum honeycomb core
Aluminum sheet
Cheesecloth, bleached, 4-ply pads
Chromate conversion coating
Cleaner, alkaline
Cloth, bleeder
Cloth, rumple, purified polishing fabric
Film, release
Film, vacuum bagging
Paint, finish
Paper, Kraft, wrapping, wax-free
Phenolic sheet, 0.125-inch
Potting compound, core and dent filler
Primer, adhesive
Primer, sealant, aerodynamic smoother
Putty, vacuum seal
Sealant, aerodynamic smoother
Solution, surface preparation
Solvent, nonchlorinated (for titanium)
Solvent, cleaning
Tape, aluminum foil 0.004 (for aluminum)
Tape, double-backed
Tape, masking, hi-temp
Tape, plastic film, nylon
Titanium, sheet
Water, distilled or demineralized

Tools or Equipment

Abrasive pads, nonwoven, nylon
Abrasive cloth or paper, wet or dry, 180, 220, 320, and 400 grit, aluminum oxide

Aspirator, vacuum
Air supply, 90 to 100 psi (w/pressure regulator, filter, and oil trap)
Blanket, insulation
Blanket, heater, electric
Brush, acid, 3/8- by 1-inch
Brush, paint, short bristle, 1-1/2-inch
Containers, mixing, polyethylene
Controller, electrical, Variac or power stat, adjustable, ac
Drills, assorted sizes
Drill motor, pneumatic or electric (explosionproof in fuel areas)
Emery cloth, 150, 320, and 500 grit, aluminum oxide (for titanium)
Fillet gun, sealant
Fly cutter
Gage, air pressure, 100 psi
Gage, vacuum, 32 in. Hg
Gloves, heat insulating
Gloves, white cotton fiber
Gloves, rubber or neoprene, surgeons'
Heat lamps, 200 to 350 watt (explosionproof)
Hole saw assembly
Hose, vacuum w/fittings
Knife, core cutting
Knife, putty
Knife, pocket
Micrometer, depth
Micro stop, drill
Pen, ink marking
Power supply, 115 volt, 60 cycle, ac
Pressure plate, 0.125- and 0.250-inch aluminum
Probes, vacuum, connector
Pyrometer, 0° to 400° F, automatic recording
Rod, mixing, metal or plastic
Router bits, assorted sizes
Router motor, pneumatic or electric (explosionproof for fuel areas)
Router templates
Safety glasses or shield
Scribe
Spatula, wood or metal
Tin snips, metal cutting
Vacuum cleaner, industrial or hand-type
Vacuum source
Wire, thermocouple, type J or equivalent

6.5.1 HONEYCOMB CORE PLUG REPAIR

Two types of repair are presented. One covers the situation for thick sandwich where the repair extends only partially through the depth. The other is for a repair where the full depth of core is replaced. These repairs are shown schematically in figure 6-13. The repair steps are as follows:

1. Apply masking around the repair area to prevent further damage during rework and to contain chemicals or acids. Use aluminum foil or polyester tape for aluminum and lead foil or polyester tape for titanium.

2. Using an ink pencil, draw coordinates which, if extended, would pass through the center of the damaged area (fig. 6-14).

3. Determine if a hole saw or router is best suited for removing the damaged material. Proceed to section 8.1.1 or 8.1.2 for instructions.

   NOTE: Inspect for moisture or corrosion. If moisture or corrosion is present its extent must be determined and it must be removed. If the repair area is contaminated with fuel or hydraulic fluid, use MEK or another suitable solvent, and a brush to clean. Be sure the area is free from contamination and dry before proceeding with the repair.

4. When damage removal is complete per section 8.1, mount a mushroom-type sanding arbor in an air motor. Attach a small diameter 220- to 320-grit aluminum oxide disc. Remove the remaining core ends and adhesive fillets to a smooth finish. If bare skin is exposed through the adhesive film, reclean per section 5.3. This is a faying surface for rebonding later in the repair sequence.

5. Remove the sanding dust and debris with a vacuum cleaner.

6. Dry wipe with clean dry cheesecloth or rumple cloth pads.

7. If assembly cannot be continued for 30 minutes or more, cover with clean wax-free Kraft paper.

8. Core plug fabrication

   a. Cut and fit a core plug. Select the core density, cell size and alloy to be the same as that used in the original construction. Instructions for cutting the core details are given in section 6.1.2.

   b. Trim the plug to a loose fit in the routed cavity. Trim the core surface to be flush with the surface of the skin.

   c. Carefully remove the trimmed core plug from the machined cavity.

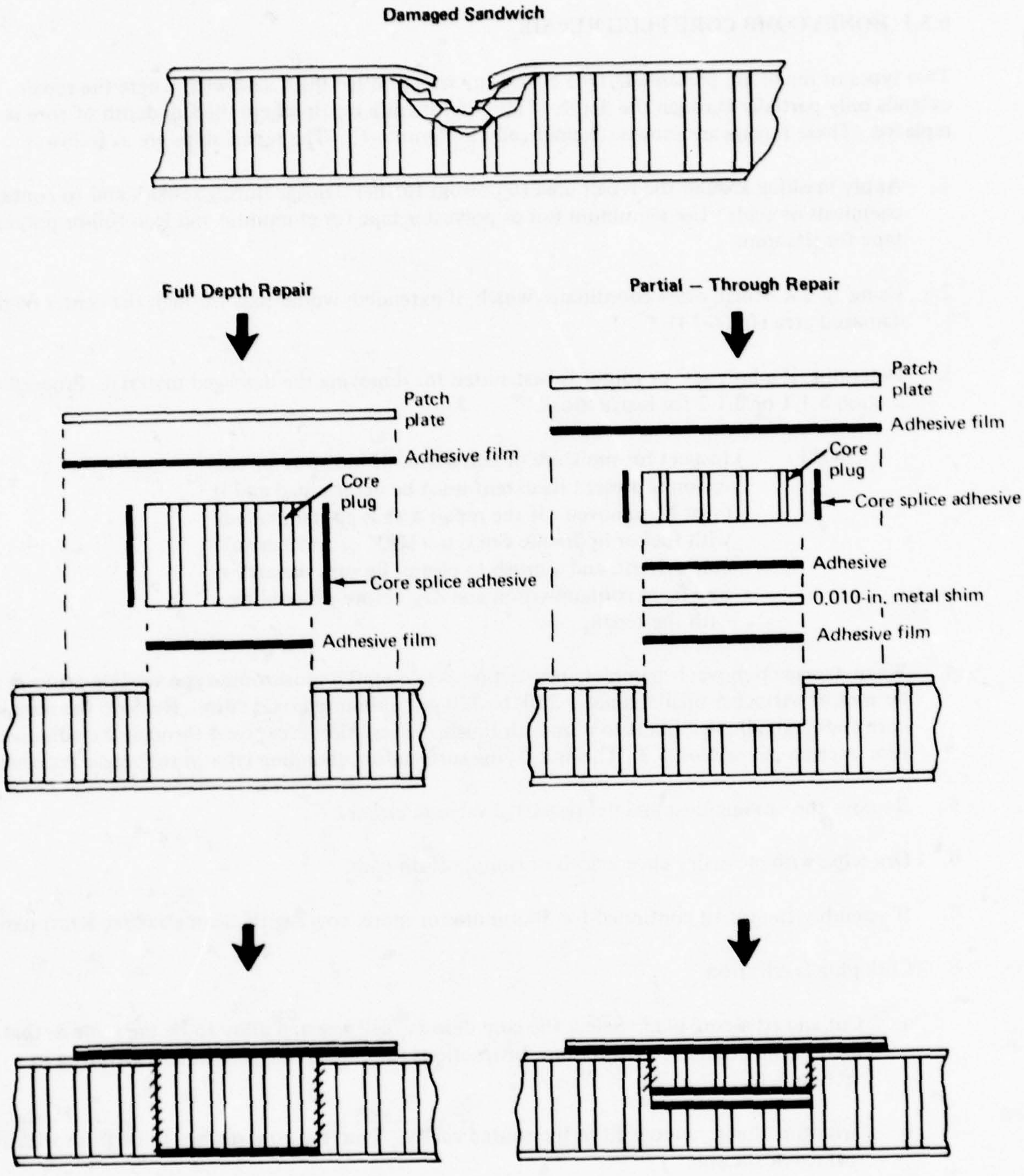


Figure 6-13.—Schematic of Repair for Damage to One Sandwich Face and Core

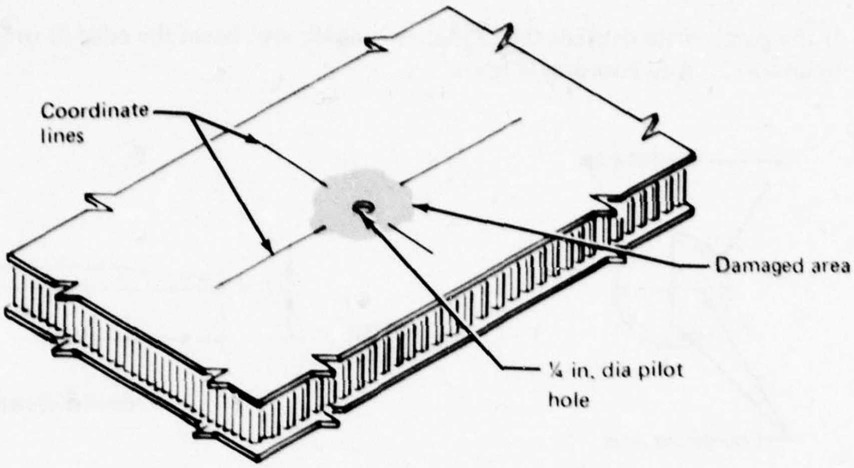


Figure 6-14.—Marked Coordinate Lines for Centering Patch Over Core Plug Repair

d. Clean the core plug per section 5.2.

- Use trichloroethane or other approved degreasers.

CAUTION **Clean White Cotton Lintless Gloves Shall Be Worn When Handling Cleaned Details or the Adhesive.**

- Use caution while cleaning the core plug.

- Play air over the plug until all odor of cleaning solvent is removed. Be careful not to damage the cell walls with an air blast. Carefully shaking the core plug to remove the solvent is acceptable.

e. Wrap the core plug in clean, wax-free Kraft paper until needed for assembly.

9. Fabricate the patch plate:

a. Select the material to be the same as the sandwich face material that is being patched. The gage should be the same as that of the face material or, if not available, the next heavier gage.

b. Cut out the patch plate to be the diameter of the hole plus the allowance for overlap. The overlap should be a minimum of 1.0 inch or as designated by the responsible engineering authority.

c. If the patch plate exceeds 0.025 inches in thickness, bevel the edge of one side as shown in figure 6-15. Add coordinate lines.

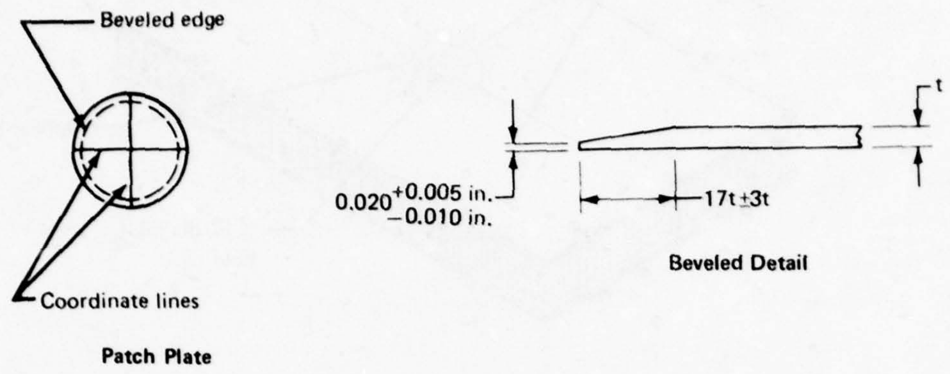


Figure 6-15.—Detail of Beveled Patch Plate and Coordinate Lines

10. Prepare the adhesive and metal shim:

    a. Select the appropriate adhesive film per section 4.2 or the applicable aircraft T.O. Observe precautionary notes when removing refrigerated material from storage. Do not touch the adhesive with bare hands.

    b. Cut one disk of adhesive to the same size as the repair cut-out (cut out two disks if a partial-through repair is being made (see fig. 6-13).

    c. If a partial-through repair is being made, also cut out a 0.010-inch-thick aluminum shim the same size as the repair cut-out.

    d. Preassemble details to ensure proper fit.

11. Prepare both surfaces of the metal shim (if used) for adhesive bonding per section 5.3 or 5.4. Wipe the bottom and sides of the cut-out area with solvent (see sec. 4.2). Allow the area to dry.

CAUTION: **Once the Cleaning Procedure Starts, DO NOT TOUCH With Bare Hands or Contaminate Any Surface To Be Filled, Coated, or Bonded.**

DO NOT Allow Solution to Enter the Assembly or Contact the Previously Cured Adhesive.

CAUTION: **Observe Requirements for a Clean Environment.**

Wear Clean White Cotton Lintless Gloves When Handling Clean Details or Adhesives.

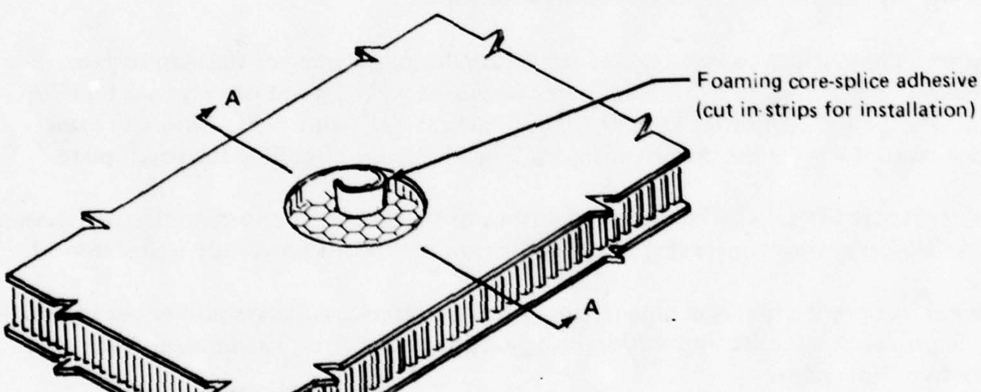
12. Assemble the repair details for initial bonding:

   a. Remove separator film from one of the adhesive disks and position the adhesive film in the bottom of the cut-out.

   b. If a partial-through repair is being made, place the 0.010 inch metal shim on top of the adhesive. Cover with the second adhesive disk. Be sure to remove the separator film.

   c. Position a layer of 0.050 or 0.100 inch core splice adhesive foam tape around the inside edge of the cavity (see fig. 6-16).

   d. Carefully insert the core plug into the cavity. Orient the ribbon direction of the core plug foil to be the same as that of the sandwich core. Be careful not to push the adhesive tape down the side of the cavity as the core is inserted. Fill any voids with additional adhesive foam tape. The core plug should extend slightly above (approx 0.010 in.) the face surface.



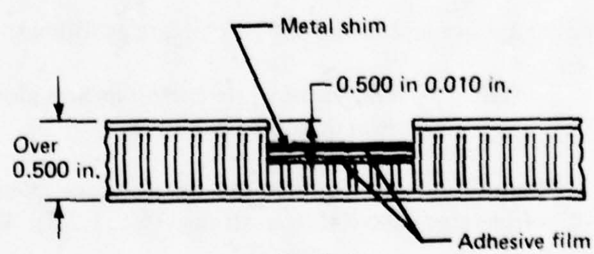


Figure 6-16.—Application of Core-Splice Adhesive and Metal Shim Plug for a Partial Through-Repair

13. Locate three thermocouples, equally spaced around the core plug. Fasten in place using nylon or polyester tape.

14. Prepare the repair area for initial bonding in accordance with section 7.11.

15. Bond the repair per requirements for the selected adhesive systems in table 4-3.

    NOTE: Once the curing cycle has started, continue until the cycle is complete.

16. Remove the bonding equipment after the cure cycle is complete.

    WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT PARTS OR TOOLS.

17. Visually inspect the core plug for a homogeneous bond. If voids are present in the bondline, fill with a core splice adhesive paste per section 4.2. Cure at the required temperature.

18. Sand the core flush with the skin surface using 320-grit abrasive paper. Remove sanding debris from the core cells with vacuum or clean dry compressed air. Use care not to damage the core cells.

19. After removing sanding dust, wipe surface of core with solvent. Dry with clean dry cheesecloth and clean dry compressed air to remove all trace of solvent.

20. Mask the core plug surface to prevent contamination during cleaning of the skin surface. Use aluminum foil or polyester tape for aluminum assemblies and lead foil or polyester tape for titanium. Overlap the skin surface 0.060 ± 0.020 inches. See figure 6-11. Similarly mask around the cut-out leaving the area clear that will be cleaned for bonding the patch plate.

21. Chemically prepare the skin surface and the surface of the patch plate for bonding per section 5.3 or 5.4. Observe notes concerning safety and cleanliness noted previously under step 11.

22. After the surface preparation is complete, apply the appropriate adhesive primer per section 4.3. Should the primer or adhesive application be delayed for more than 30 minutes, cover with clean wax-free Kraft paper.

23. Apply adhesive and install the patch plate as follows:

    NOTE: Wear clean white cotton lintless gloves when handling clean details or adhesives.

    a. Remove the required adhesive from storage. Observe precautionary notes when removing refrigerated material from storage (sec. 1.2.5). Do not touch the adhesive with bare hands.

    b. Using the patch plate as a template, cut an adhesive disk to the patch plate size.

c. Remove the separator film from the adhesive disk. Remove the masking tape covering the core plug and that masking the surrounding area.

d. Apply the adhesive disk and the patch plate (beveled side up) over the cut-out area. Use the coordinate lines for alignment.

e. Secure the patch plate with nylon or polyester film tape (see fig. 6-17).

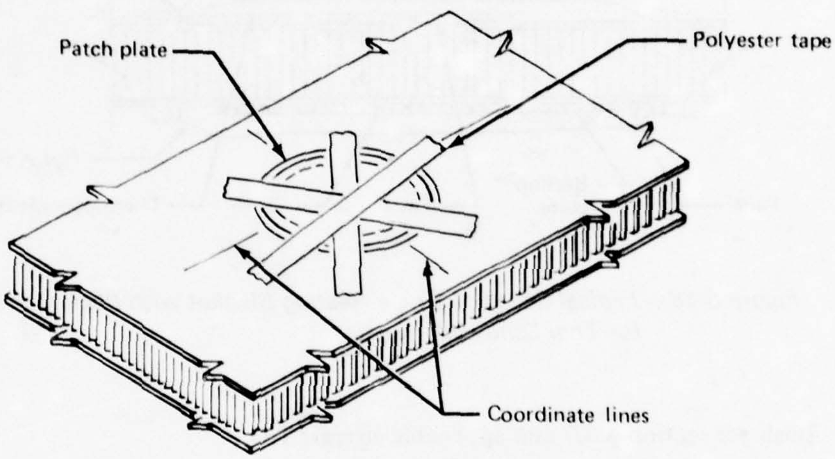


Figure 6-17.—Patch Plate Secured With Polyester Tape

24. Prepare the repair for bonding in accordance with section 7.11. See figure 6-18.

NOTE: For assurance of a quality bond, heat must be applied to both surfaces of the sandwich when the assembly is thicker than 1/2 inch.

25. Bond the repair per requirements for the selected adhesive system in section 4.2.

26. Remove bonding equipment after cure cycle is complete.

WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT PARTS OR EQUIPMENT.

27. Remove excess adhesive (sec. 7.12).

28. Seal around edge of patch plate with sealing compound (refer to sec. 4.2 and 4.and 4.3.6).

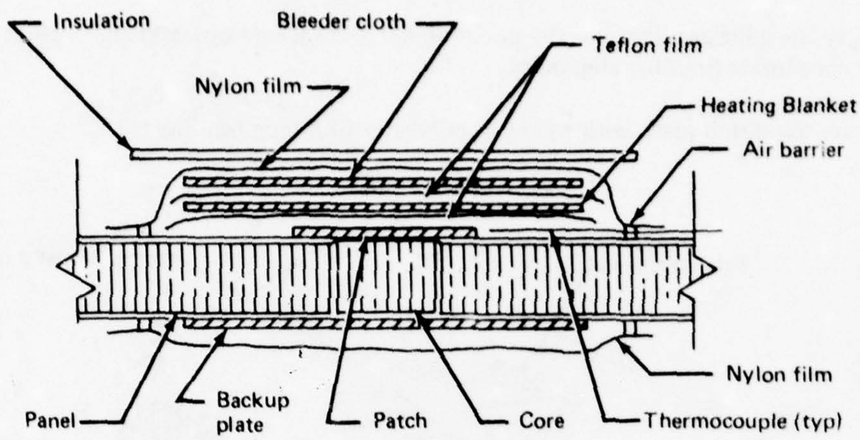


Figure 6-18.—Typical Setup of Single Heating Blanket with Backup Pressure for Thin Sandwich Repair

29. Apply finish per section 4.3.7 and applicable aircraft T.O.

6.5.2 POTTED PLUG REPAIR, OPTIONAL METHOD (NEEDS ENGINEERING APPROVAL)

1. Preparation of the repair area prior to insertion of the potting compound is the same as that for the honeycomb core plug repair described in 6.5.1. Start the repair by performing steps given in section 6.5.1, steps 1 through 8.

2. Select and prepare the potting compound per instructions given in section 4.3.4.

3. Wipe the bottom and sides of the cut-out area with solvent. Allow the area to dry.

4. Fill the core cavity using the prepared potting compound. Pack the cavity until the compound is approximately 0.020 inches above the skin surface.

5. Remove excess compound from the panel surface using cheesecloth moistened with acetone.

   WARNING: SPECIAL PRECAUTIONS TO BE USED WHILE HANDLING SOLVENTS ARE NOTED IN SECTION 1.3.

   Do not remove the coordinate lines from the skin surface. Allow cleaned area to dry for approximately 15 minutes.

6. If a room-temperature-curing potting compound is used, allow the material to cure for the time period designated in table 4-3. Acceleration of the cure with heat lamps may be permitted. DO NOT OVERHEAT. After curing, proceed with step 12.

   If a potting compound requiring an elevated-temperature cure is used, proceed with step 7.

7. Apply two layers of nylon or polyester film tape over the routed hole and potting compound as shown in figure 6-19.

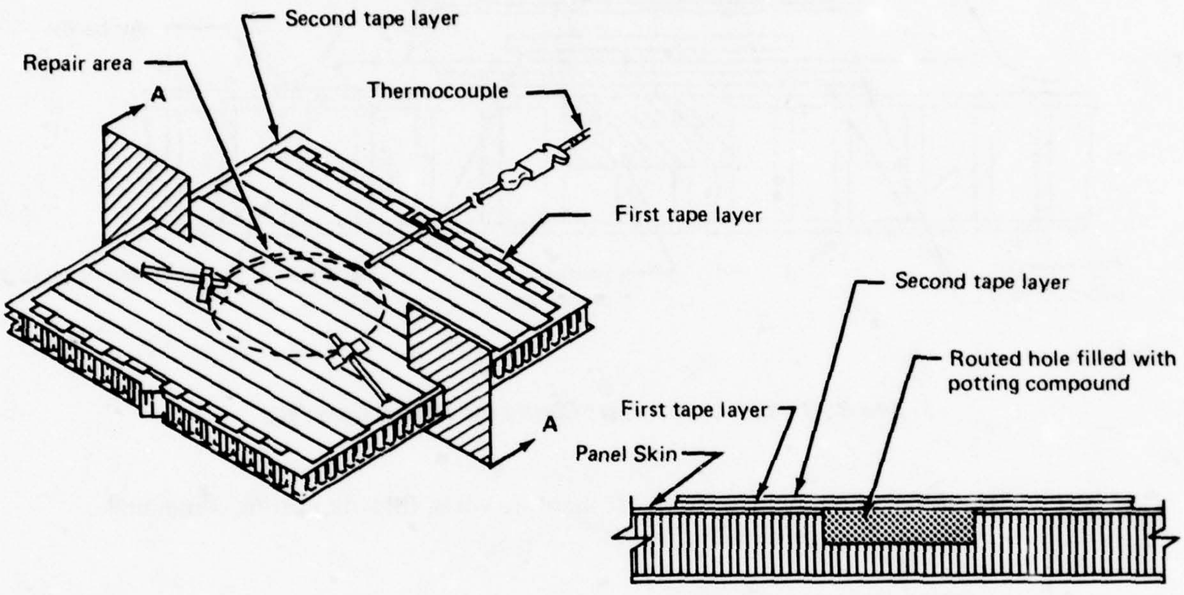


Figure 6-19.—Application of Masking Tape Over Potted Plug Repair

8. Locate three thermocouples equally spaced around the potted area. Fasten in place with nylon or polyester tape.

9. Prepare the potted area for curing by applying a release film, caul plate, heating blanket, vacuum bagging film, etc. See section 7.11 and figure 6-20. Normally the patch plate can be used for the caul plate unless it is quite thin, i.e., less than 0.030 inch.

10. Cure the assembly per requirements for the selected potting compound as indicated in table 4-3.

11. Remove the bonding equipment and material after the cure cycle is complete.

WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT PARTS OR TOOLS.

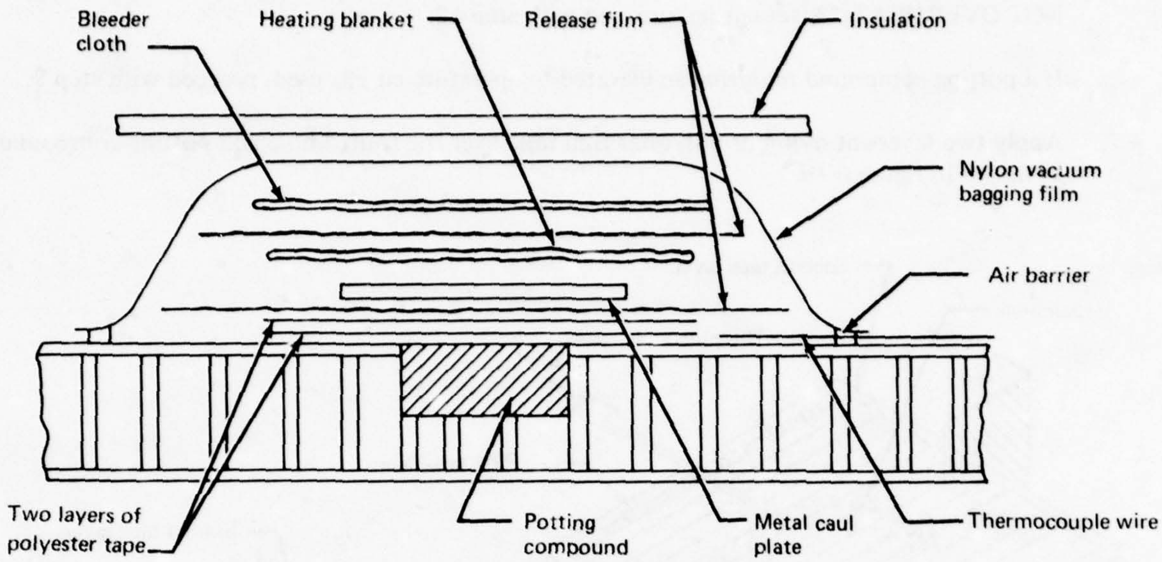


Figure 6-20.—Lay-Up for Heat Curing the Potted Core Plug

12. Visually inspect the potted plug for voids. If there are voids, fill with potting compound. Cure at room temperature or with heat lamps.

13. Smooth the potted surface as follows:

    a. Sand the potted surface to 0.000 to 0.005 inch above the skin surface using 320-grit abrasive paper.

    b. Remove sanding debris from the area with clean, dry compressed air or vacuum cleaner.

    c. Wipe the area with clean dry cheesecloth.

14. Continue the repair using steps 21 through 29 in section 6.5.1.

6.6 HOLE THROUGH BOTH SANDWICH SKINS

These repair methods apply when both skins and the honeycomb core of a sandwich panel have been damaged (fig. 6-21). Three types of repairs are presented. These include (1) a honeycomb core plug, nonflush, (2) a potted plug, nonflush, optional, and (3) a honeycomb core plug, flush one side. The use of potting to replace the damaged core should be considered only for very small areas and with approval of the responsible maintenance engineer. Other limitations apply that are designated in the specific aircraft model's T.O. manual. Instruction for the repair of more extensive damage is given in section 7.0.

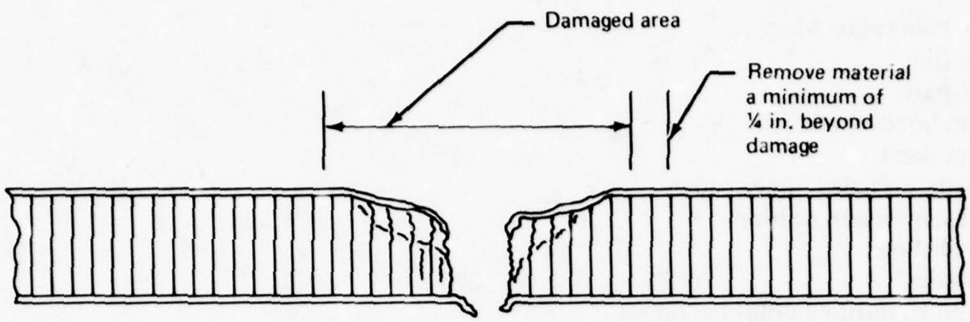


Figure 6-21.—Damage Through Both Skins and Honeycomb Core

During the repair activity, give special attention to the following items:

WARNING: **OBSERVE ALL LOCAL SAFETY PRECAUTIONS AND THOSE DESIGNATED IN SECTION 1.3.**

DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH A GENEROUS AMOUNT OF CLEAN WATER.

ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND SOLUTIONS.

IF THE REPAIR IS IN A FUEL TANK AREA THE FUEL TANK PRESSURE SHALL BE RELIEVED PRIOR TO STARTING THE REPAIR. OBSERVE OTHER PRECAUTIONARY PROCEDURES AS DESIGNATED BY THE SAFETY OFFICER.

The following lists indicate the types of materials and equipment required. Refer to section 4.2 for specific information and application instructions for materials. Refer to section 8.0 for more detailed information concerning tools and equipment.

Materials

Adhesive, core splice foam
Adhesive, film
Adhesive, paste
Aluminum honeycomb core
Aluminum sheet
Cheesecloth, bleached, 4-ply pads
Chromate conversion coating
Cleaner, alkaline
Cloth, bleeder
Cloth, rumple, purified polishing fabric
Film, release
Film, vacuum bagging
Paint, finish
Paper, Kraft, wrapping, wax-free
Phenolic sheet, 0.125-inch
Potting compound, core and dent filler
Primer, adhesive
Primer, sealant
Putty, vacuum seal
Sealant
Solution, surface preparation
Solvent, nonchlorinated (for titanium)
Solvent, cleaning
Tape, aluminum foil 0.004 (for aluminum)
Tape, double-backed
Tape, lead foil (for titanium)
Tape, masking, hi-temp
Tape, plastic film, nylon
Titanium, sheet
Water, distilled or demineralized

Tools or Equipment

Abrasive pads, nonwoven, nylon
Abrasive cloth or paper, wet or dry, 180, 220, 320, and 400 grit, aluminum oxide
Aspirator, vacuum
Air supply, 90 to 100 psi (w/pressure regulator, filter, and oil trap)
Blanket, insulating
Blanket, heater, electric
Brush, acid, 3/8- by 1-inch
Brush, paint, short bristle, 1-1/2-inch
Containers, mixing, polyethylene
Controller, electrical, Variac or power stat, adjustable, ac
Drills, assorted sizes

Drill motor, pneumatic or electric (explosionproof in fuel areas)
Emery cloth, 150, 320, and 400 grit, aluminum oxide (for titanium)
Fillet gun, sealant
Fly cutter
Gage, air pressure, 100 psi
Gage, vacuum, 32 in. Hg
Gloves, heat insulating
Gloves, white cotton fiber
Gloves, rubber or neoprene, surgeons'
Heat lamps, 200 to 350 watt (explosionproof)
Hole saw assembly
Hose, vacuum w/fittings
Knife, core cutting
Knife, putty
Knife, pocket
Micrometer, depth
Micro stop, drill
Pen, ink marking
Power supply, 115 volt, 60 cycle, ac
Pressure plate, 0.125- and 0.250-inch aluminum
Probes, vacuum connector
Pyrometer, 0° to 400° F, automatic recording
Rod, mixing, metal or plastic
Router bits, assorted sizes
Router motor, pneumatic or electric (explosionproof for fuel areas)
Router templates
Safety glasses or shield
Scribe
Spatula, wood or metal
Tin snips, metal cutting
Vacuum cleaner, industrial or hand-type
Vacuum source
Wire, thermocouple, type J or equivalent

6.6.1 HONEYCOMB CORE PLUG REPAIR, NONFLUSH

The repair is shown schematically in figure 6-22.

The repair steps are as follows:

1. Apply masking tape around the damaged area to prevent further damage from rework and to contain cleaning chemicals or acids. Use aluminum foil or polyester tape for aluminum and lead foil or polyester tape for titanium.

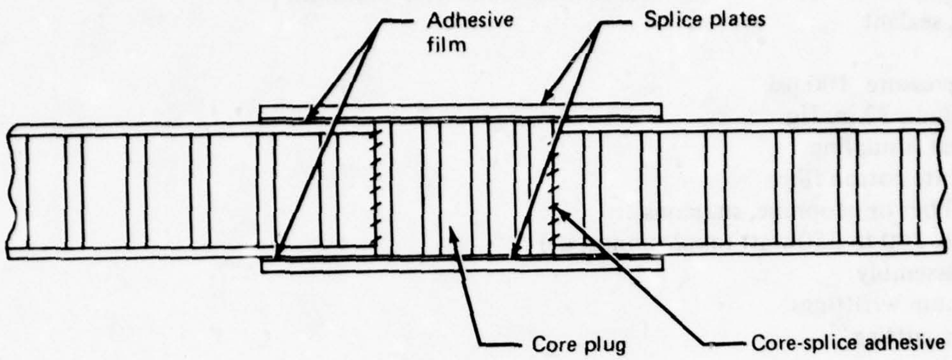


Figure 6-22.—Schematic of Repair Using Nonflush Honeycomb Core Plug

Using an ink pencil, draw coordinates which, if extended, would pass through the center of the damaged area (see fig. 6-23).

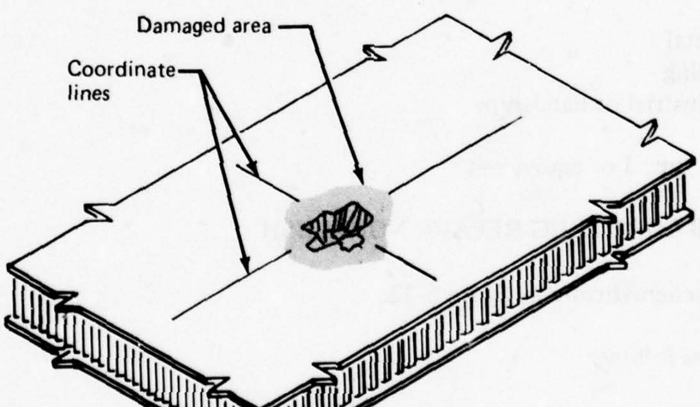


Figure 6-23.—Marked Coordinate Lines for Centering Patch Over Core Plug Repair

3. Determine if a hole saw or router is most suitable, and remove the damaged material. For instructions on use of a hole saw or router, refer to section 8.1.1 or 8.1.2.

4. Use a vacuum cleaner to remove dust or debris from the repair area. Inspect for internal corrosion or moisture.

NOTE: If moisture or corrosion is present, its extent must be determined and it must be removed.

If the repair area is contaminated with fuel or hydraulic fluid, use MEK or another suitable solvent and a brush to clean. Be sure the area is free of contamination and dry before proceeding with the repair.

5. Fabricate the patch plates:

a. Patch plates are required for both the outer and inner skins. Select the material to be the same as the sandwich face material that is being patched. The gage should be the same as that of the original face material or, if not available, the next higher gage.

b. Cut out the patch plate to be the diameter of the hole plus the allowance for overlap. The overlap should be a minimum of 1.0 inch or as specified by the responsible engineering authority.

c. If the thickness of the patch plates exceeds 0.025 inch, bevel one side as shown in figure 6-24. Add coordinate lines for positioning.

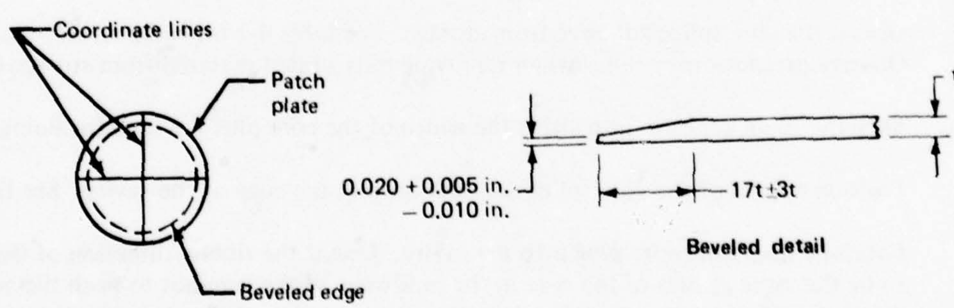


Figure 6-24.–Detail of Beveled Patch Plate and Coordinate Lines

6. Core plug fabrication:

a. Cut and fit a core plug. Select the core density, cell size, and alloy to be the same as that used in the original construction. Instructions for cutting the core details are given in section 6.1.2.

b. Trim the edges of the plug to a loose fit in the routed cavity. Trim the core surface to be flush with the outer surface of the two skins.

c. Carefully remove the trimmed core plug from the machined cavity.

d. Clean the core plug per section 5.2.

- Use trichloroethane or another suitable solvent for aluminum core.

- Use caution while cleaning the core plug.

- Play air over the plug until all odor of cleaning solvent is removed. Do not damage the cell walls with an air blast. Carefully shaking the core plug to remove the solvent is acceptable.

NOTE: Wear clean white cotton gloves when handling the clean core details or adhesives.

7. Prepare the repair area for bonding in the core plug. Wipe the edges of the core in the cavity with solvent. Dry with clean dry cheesecloth and clean dry compressed air to remove all trace of solvent.

8. Install and bond the core plug as follows:

a. Obtain the core splice adhesive from storage. See table 4-1 for material selection. Observe precautionary notes when removing refrigerated material from storage (sec. 1.2.5).

b. Slice the foam adhesive into strips the width of the core plus 1/8 inch for lining the cavity.

c. Position a layer of the core splice adhesive around the edge of the cavity. See figure 6-25.

Carefully insert the core plug into the cavity. Orient the ribbon direction of the plug foils to be the same as that of the core in the sandwich. Take care not to push the adhesive down the side of the cavity when inserting the core plug. Fill any voids with extra core splice adhesive.

d. Place a layer of release film over each end of the core plug. Using the patch plates as caul plates, locate the patch plates over the release film. Secure in place with polyester or nylon film tape.

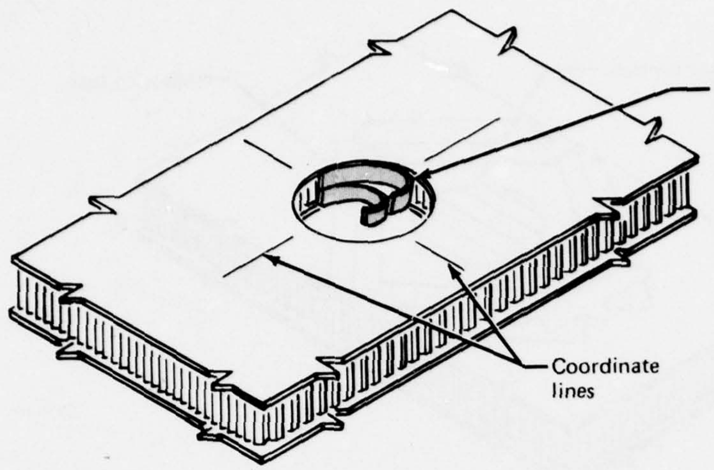


Figure 6.25.—Application of Core-Splice Adhesive to Core Plug Repair

e. Using the standard bonding procedure described in section 7.11, vacuum bag the repair area and cure the core splice adhesive per instructions in section 4.2.

f. After the cure has been completed, debag the assembly.

CAUTION: Wear Heat Insulating Gloves When Handling Hot Tools or Parts.

9. Inspect the core plug for a homogeneous bond. If voids appear in the bondline, fill with additional core splice adhesive foam. Cure at the recommended temperature.

10. Sand the core surface flush with the skin surface. Remove the sanding debris with clean dry compressed air or vacuum.

11. Wipe both surfaces of the core plug with cheesecloth moistened with cleaning solvent (refer to sec. 4.2). Dry to remove all trace of solvent.

12. Mask the core plug surfaces to prevent contamination during preparation of the skin surfaces for bonding the patch plates. Use aluminum foil or polyester tape for aluminum skins and lead foil or polyester tape for titaanium. Overlap the skin edges by approximately 0.060 ± 0.020 inch. Similarly mask around the cut-out leaving the area clear that will be cleaned for bonding the patch plate. See figure 6-26.

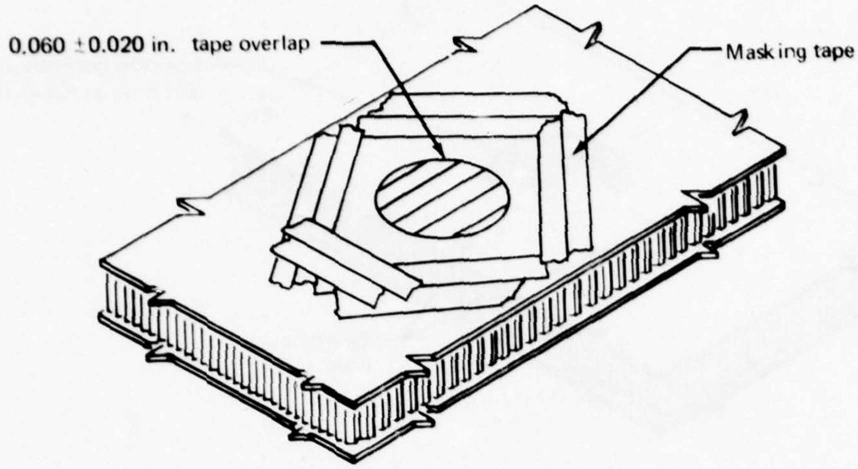


Figure 6-26.—Application of Masking Tape Prior to Surface Cleaning

15. Prepare the adhesive:

    a. Select the appropriate adhesive per section 4.2. Observe precautionary notes when removing refrigerated material from storage (sec. 1.2.5). Do not touch the adhesive with bare hands.

    b. Cut two disks of adhesive the same size as the patch plates. The patch plates may be used as templates.

16. Chemically prepare the skin surfaces and the surfaces of the patch plates for bonding per instructions in sections 5.3 or 5.4. Observe notes regarding cleanliness and safety:

    WARNING: **DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH GENEROUS AMOUNTS OF CLEAN WATER.**

    ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND CLEANING SOLUTIONS.

    CAUTION: **Once the Cleaning Procedure Starts, DO NOT TOUCH With Bare Hands or Contaminate Any Surface to Be Filled, Coated, or Bonded.**

CAUTION: DO NOT Allow Solutions to Enter the Assembly or Contact the Previously Cured Adhesive.

Observe Requirements for a Clean Environment.

17. After the surface preparation is complete, apply the appropriate adhesive primer per section 4.3.1. Should the primer or adhesive application be delayed for more than 30 minutes, cover with clean wax-free Kraft paper.

18. Apply adhesive and install the patch plates as follows:

    a. Remove the separator film from the adhesive disks. Remove the masking tape covering the core plug and that masking the surrounding area.

    b. Apply the adhesive disks and the patch plates (beveled side up) over the cut-out areas. Use the coordinate lines for alignment.

    c. Secure the patch plate with polyester or nylon film tape (see fig. 6-27).

    d. Attach a minimum of three thermocouples around the patch plate. Secure in place with nylon or polyester film tape.

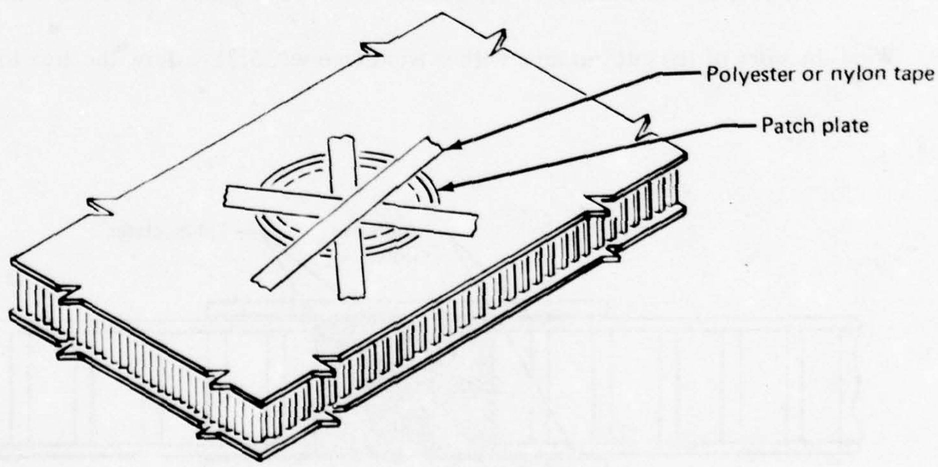


Figure 6-27.—Patch Plate Secured With Polyester or Nylon Tape

19. Prepare the repair for bonding in accordance with section 7.11.

NOTE: For assurance of a quality bond, heat must be applied to both surfaces of the sandwich when the assembly is thicker than 1/2 inch.

20. Bond the repair per requirements for the selected adhesive system in section 4.2.

21. Remove bonding equipment after cure cycle is complete.

WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT PARTS OR EQUIPMENT.

22. Remove excess adhesive flash (sec. 7.12).

23. Seal around edge of the patch plate with sealing compound, refer to section 4.3.6.

24. Apply finish per section 4.3.7 and the applicable aircraft T.O.

6.6.2 POTTED PLUG REPAIR, OPTIONAL METHOD (NEEDS ENGINEERING APPROVAL)

The completed repair is shown in figure 6-28. Instructions for making the repair are as follows:

1. Preparation of the repair area prior to insertion of the potting compound is the same as that for the honeycomb core plug repair described in section 6.6.1. Start the repair by performing steps given in section 6.6.1 steps 1 through 6.

2. Select and prepare the potting compound per instructions given in section 4.2 and 4.3.4.

3. Wipe the sides of the cut-out area with solvent (see sec. 5.2). Allow the area to dry.

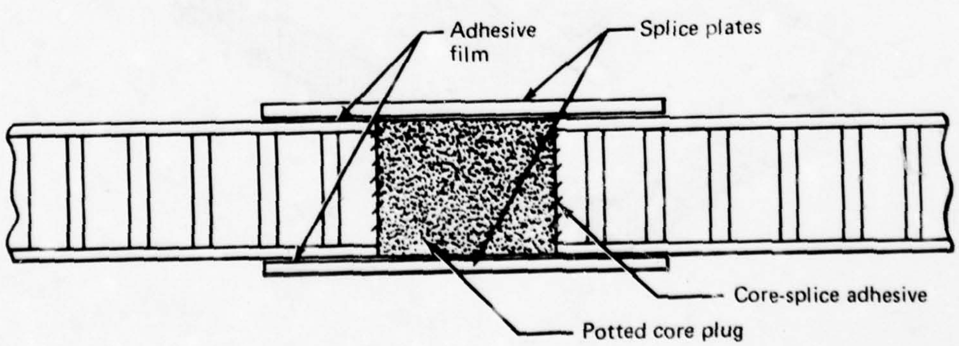


Figure 6-28.—Schematic of Repair Using Potted Core Plug

4. Fill the core cavity using the prepared potting compound. To facilitate this, attach a layer of release film and an aluminum plate over the hole opposite the fill side using nylon or polyester tape. Pack the cavity until the compound is approximately 0.020 inch above the skin surface.

5. Remove excess compound from the panel surface using cheesecloth moistened with acetone or another suitable solvent. Take care to keep excess solvent out of the potting-compound-filled area. Do not remove the coordinate lines from the skin surface. Allow cleaned area to dry for approximately 15 minutes.

WARNING: SPECIAL PRECAUTIONS TO BE USED WHILE HANDLING SOLVENTS ARE NOTED IN SECTION 1.3.

6. If a room-temperature-curing potting compound is used, allow the material to cure for the time period designated in section 4.2. Acceleration of the cure with heat lamps may be permitted. DO NOT OVERHEAT. After curing, proceed with step 11.

   If a potting compound requiring an elevated-temperature cure is used, proceed with step 7.

7. Apply two layers of nylon or polyester film tape over the routed hole and potting compound as shown in figure 6-19.

8. Prepare the potted area for curing by applying a release film, caul plate, heating blanket, vacuum bagging film, etc. See section 7.11 and figure 6-20. Normally the patch plates can be used for the caul plates, i.e., tooling plates to distribute the pressure flatly over the surface, unless they are quite thin, i.e., less than 0.030 inches. See figure 6-29.

9. Cure the assembly per requirements for the selected potting compound as indicated in table 4-3.

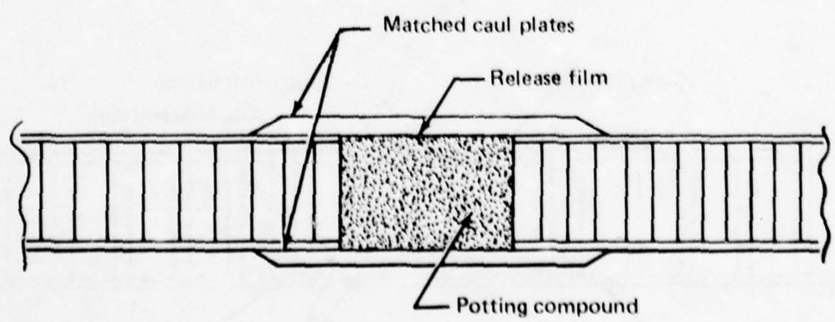


Figure 6-29.—Patch Plates Used as Caul Plates to Cure Potting Compound

10. Remove the bonding equipment after the cure cycle is complete.

WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT PARTS OR TOOLS.

11. Inspect the potted plug for voids per section 10.0. If there are voids, fill with potting. Cure at room temperature or by heating. See the applicable T.O. for limits and precautions.

12. Smooth the potted surface as follows:

    a. Sand the potted surface to 0.000 to 0.005 inch above the skin surface using 320-grit abrasive paper.

    b. Remove sanding debris from the area with clean, dry compressed air or vacuum.

    c. Wipe the area with clean dry cheesecloth.

13. Continue the repair using steps 14 through 24 in section 6.6.1.

6.6.3 HONEYCOMB CORE PLUG REPAIR, FLUSH ONE SURFACE

The sketch of the repair is shown in figure 6-30. Instructions for accomplishing the repair are as follows:

1. Apply masking tape around the damaged area to prevent further damage during rework and to contain cleaning chemicals. Use aluminum foil or polyester tape for aluminum and lead foil or polyester tape for titanium.

2. Using an ink pencil, draw coordinates which, if extended, would pass through the center of the damaged area (see figure 6-31).

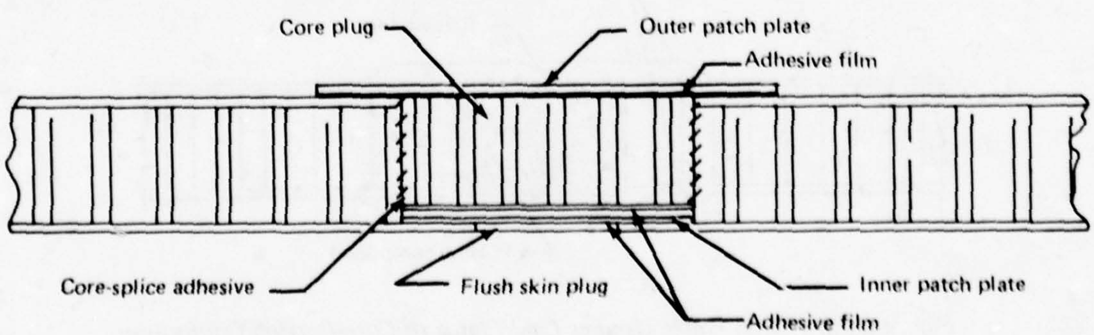


Figure 6-30.—Schematic of Repair, Flush One Side, for Hole Through Both Sandwich Skins

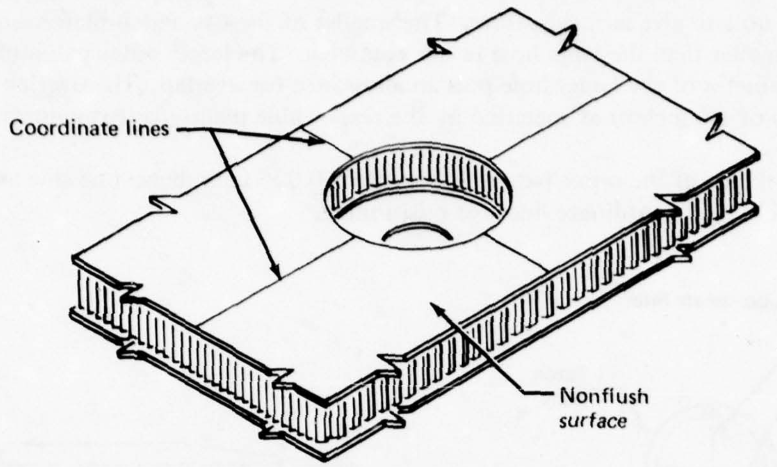


Figure 6-31.—Cavity Cleaned for Installation of Honeycomb Core Plug Repair Details

3. Determine if a hole saw or router is more suitable and remove the damaged material. For instructions on the use of a router or hole saw, refer to section 8.1.1 or 8.1.2.

4. Use a 320-grit aluminum oxide abrasive disk attached to an air motor to remove the remaining honeycomb core and loose adhesive from the inner side of the sandwich skin. See figure 6-31.

   NOTE: DO NOT SAND THROUGH the adhesive on the inner side of the skin. If it is necessary to remove the adhesive (for example because of corrosion) it will be necessary to reprepare the surface prior to bonding as instructed in section 5.0.

5. Use air pressure or vacuum to remove dust or debris from the repair area. Inspect for internal corrosion or moisture.

   NOTE: If moisture or corrosion is present, its extent must be determined and it must be removed. If the repair area is contaminated with fuel or hydraulic fluid, use MEK or other suitable solvent and a brush to clean. Be sure the area is dry and free of contamination before proceeding with the repair.

6. Fabricate the skin plug and patch plates:

   a. Patch plates are required for both the outer and inner skins, and a skin plug is required for the flush surface (see fig. 6-30). Select the material to be the same as the sandwich face material that is being patched. The gage should be the same as that of the original face material.

b. Mark and cut the skin plug and the two patch plates. The skin plug should fit snuggly in the small hole to give a flush surface. The smaller of the two patch plates should be slightly smaller than the large hole in the sandwich. The larger outer patch plate should be the diameter of the larger hole plus an allowance for overlap. The overlap should be a minimum of 1.0 inch or as specified by the responsible maintenance engineer.

c. If the thickness of the outer patch plate exceeds 0.025 inch, bevel one side as shown in figure 6-32. Add coordinate lines for positioning.

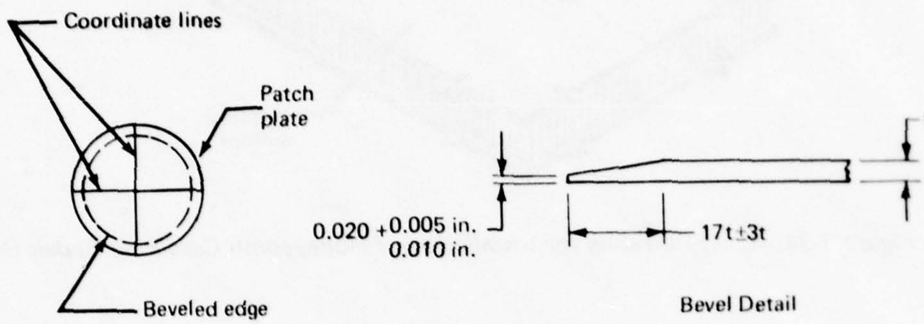


Figure 6-32.– Detail of Beveled Patch Plate and Coordinate Lines

7. Fabricate the core plug:

   a. Cut and fit a core plug. Select the core density, cell size, and alloy to be the same as that used in the original construction. Instructions for cutting the core details are given in section 6.1.2.

   b. Trim the edges of the plug to a loose fit in the routed cavity. Place the smaller of the two splice plates at the bottom of the cavity. Insert the core and trim the surface to be flush with the outer surface of the skin.

   c. Carefully remove the trimmed core plug from the machined cavity.

   d. Clean the core plug per section 5.2.

      - Use trichloroethane or other suitable solvent for aluminum core.

      - Use caution while cleaning the core plug.

      - Play air over the plug until all odor of cleaning solvent is removed. Do not damage the cell walls with an air blast. It is acceptable to carefully shake the core plug to remove the solvent.

CAUTION: **Clean White Cotton Lintless Gloves Shall be Worn When Handling Clean Details or Adhesive.**

8. Prepare the adhesive:

   a. Select the appropriate primer and adhesive film per section 4.2. Observe precautionary notes when removing refrigerated material from storage (sec. 1.2.5). Do not touch the adhesive with bare hands.

   b. Cut two disks of adhesive to the same size as the inner patch plate. Also cut one disk of adhesive the same size as the large patch plate.

9. Clean the repair cavity area using cheesecloth dampened with solvent. Do not use excess solvent. Air dry the area for a minimum of 15 minutes at room temperature.

10. Prepare the surfaces of the skin plug and the inner patch plate for bonding per instructions in section 5.3 or 5.4.

WARNING: **DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH GENEROUS AMOUNTS OF CLEAN WATER.**

ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND CLEANING SOLUTIONS.

CAUTION: **Once the Cleaning Procedure Starts, DO NOT TOUCH With Bare Hands or Contaminate Any Surface to Be Filled, Coated, or Bonded.**

DO NOT Allow the Solution to Enter the Assembly or Contact the Previously Cured Adhesive.

Observe Requirements for a Clean Environment.

11. Apply an adhesive-compatible primer to the surfaces of the inner patch plate and skin plug. See section 4.1.1 for primer selection and section 4.3.1 for application instructions. Air dry or bake primer per instructions.

12. Assemble the details for the initial cure cycle. Figure 6-33 shows an exploded view of the assembly components for the initial cure cycle.

    a. Position panel with the small hole on the bottom side. Place the skin plug in the hole. Cover with one of the smaller previously prepared disks of adhesive. Be sure to remove the separator film. Place the inner patch plate over the adhesive and then cover with a second adhesive disk (see fig. 6-34). Secure the skin plug in position on the outer surface with nylon or polyester film tape.

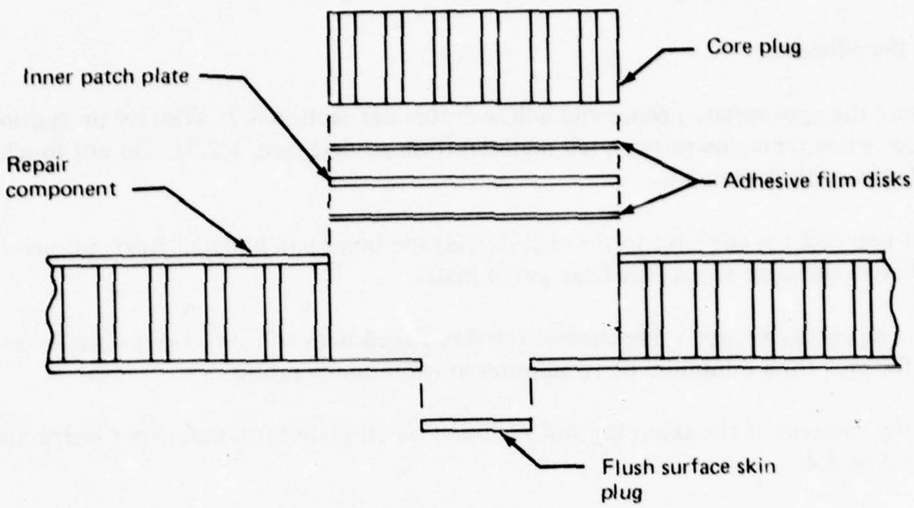


Figure 6-33.—Schematic of Repair Details for Initial Cure Cycle

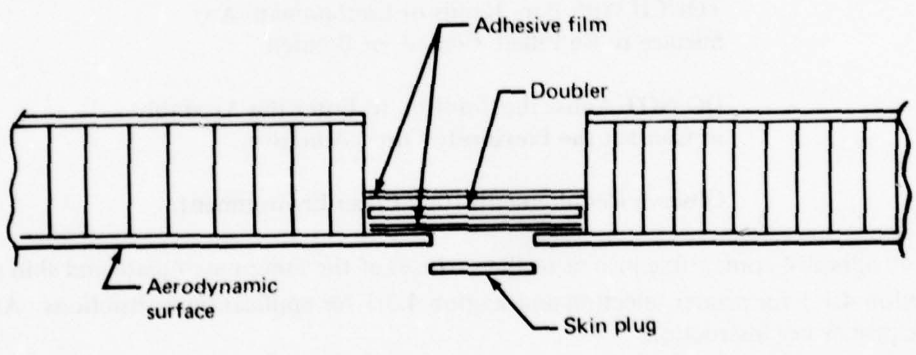


Figure 6-34.—Positioning Doubler and Skin Plug

b. Obtain the core splice adhesive from storage. See section 4.2 for material selection and processing instructions. Observe precautionary notes when removing refrigerated material from storage (sec. 1.2.5).

c. Position a layer of core splice adhesive around the edge of the cavity (see fig. 6-35).

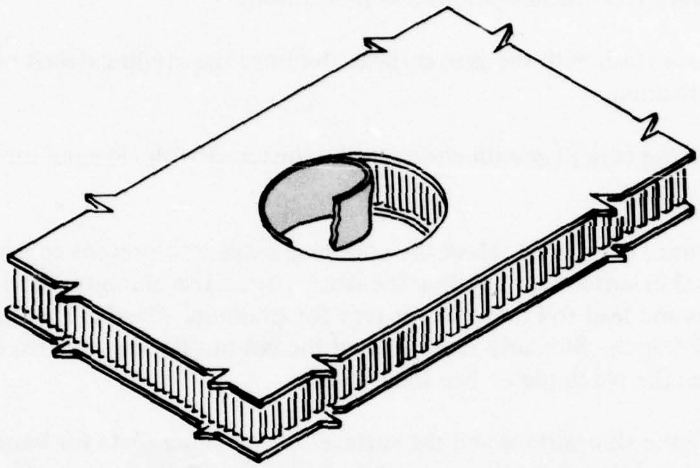


Figure 6-35.—Strip of Foaming Core-Splice Adhesive Around Edge of Cavity

d. Carefully insert the core plug into the cavity. Orient the ribbon direction of the plug foils to be the same as that of the core in the sandwich. Take care not to push the adhesive down the side of the cavity when the core is inserted. Fill any voids with extra core splice adhesive.

e. Place a layer of release film over the end of the core plug. Cover with the outer patch plate to act as a caul plate. Secure in place with plastic film tape.

f. Similarly place a layer of release film and a plate over the flush skin plug on the opposite face. Tape in place.

g. Locate a minimum of three thermocouples around the patch.

13. Using the standard bonding procedure described in section 7.11, vacuum bag the repair area and cure per instructions in section 4.2.

NOTE: For assurance of a quality bond, heat must be applied to both surfaces of the sandwich when the assembly is thicker than 1/2 inch.

14. After the cure has been completed, debag the assembly.

WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT TOOLS OR PARTS.

15. Inspect the core plug for a homogeneous bond. If voids appear in the bondline, fill with additional core splice adhesive foam. Cure at the recommended temperature using heat lamps. See the applicable aircraft T.O. for limitations and precautions.

16. Sand the core surface flush with the skin surface. Remove the sanding debris with clean dry compressed air or vacuum.

17. Wipe the surface of the core plug with cheesecloth moistened with cleaning solvent (refer to sec. 5.2).

18. Dry to remove all trace of solvent. Mask the core plug surface to prevent contamination during preparation of the skin surface for bonding the patch plate. Use aluminum foil or polyester tape for aluminum skins and lead foil or polyester tape for titanium. Overlap the skin edges by approximately 0.060 inch. Similarly mask around the cut-out leaving the area clear that will be cleaned for bonding the patch plate. See figure 6-36.

19. Chemically prepare the skin surface and the surfaces of the patch plate for bonding per instructions in section 5.3 or 5.4. Observe notes regarding cleanliness and safety as noted previously in step 10.

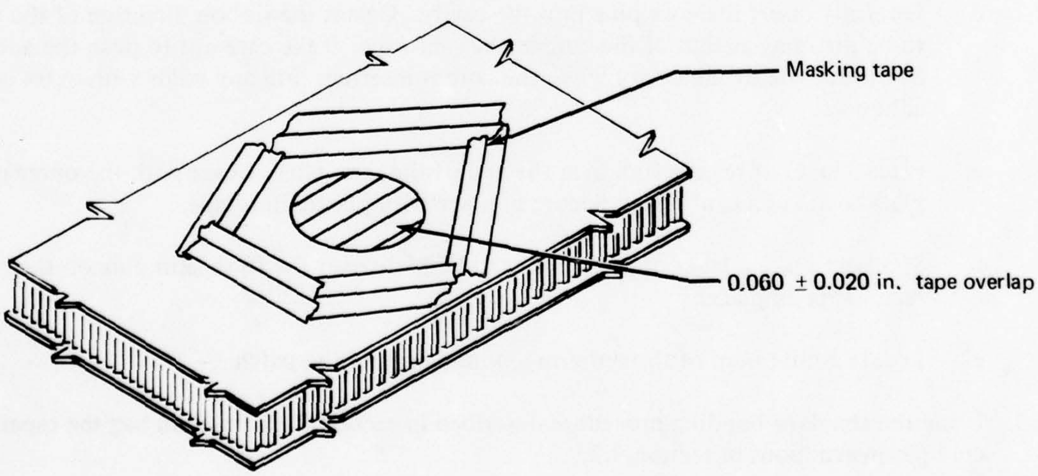


Figure 6-36.—Application of Masking Tape Prior to Surface Cleaning

20. After the surface preparation is complete, apply the appropriate adhesive primer per section 4.3.1. Should the primer or adhesive application be delayed for more than 30 minutes, cover with clean wax-free Kraft paper.

21. Apply adhesive and install the patch plates as follows:

    a. Remove the separator film from the previously prepared adhesive disk. Remove the masking tape covering the core plug and that masking the surrounding area.

    b. Apply the adhesive disk and the patch plate (beveled side up) over the cut-out area. Use the coordinate lines for alignment.

    c. Secure the patch plate with nylon or polyester film tape.

22. Prepare the repair for bonding as described in section 7.11.

    NOTE: For assurance of a quality bond, heat must be applied to BOTH surfaces of the sandwich when the assembly is thicker than 1/2 inch.

23. Bond the repair per requirements for the selected adhesive system in section 4.2.

24. Remove bonding equipment after the cure cycle is complete.

    WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT PARTS OR EQUIPMENT.

25. Remove excess adhesive flash (sec. 7.12).

26. Seal around edge of patch plate with sealing compound (refer to sec. 4.2 and 4.3.6).

27. Apply finish per section 4.3.7 and applicable aircraft T.O.

6.7 PANEL ZEE EDGE CLOSE-OUT DAMAGE

These methods apply to the repair of panel edge closure members that are fabricated from either metal or fiberglass cloth and are a 45° or 90° configuration. Typical damage of this type is shown in figure 6-37.

When the extent of damage is beyond the scope of the small area repairs, the repairs will be made per the large area repair techniques outlined in section 7.0. Nondestructive inspection procedures to determine the damage extent are described in section 10.0.

The edge of a panel is typically a metal laminate that fits against some internal member. This is usually the structural member to which the panel is mechanically attached. In such a case, it is desirable to maintain the internal thickness level and the patch must be added on the external side of the panel.

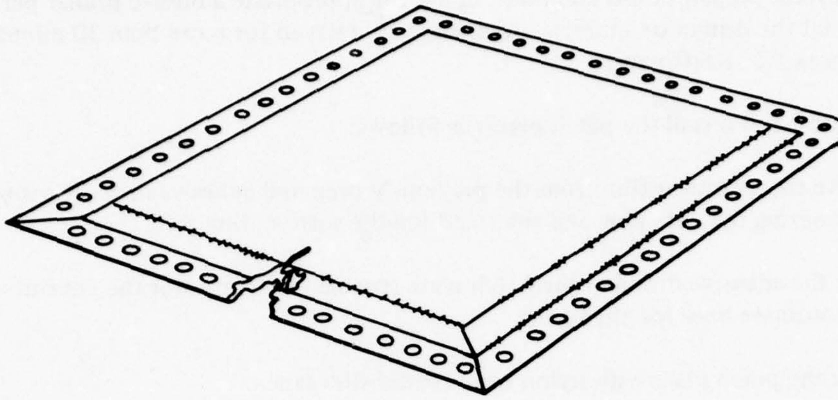


Figure 6-37.—Typical Edge Close-Out Damage

During the repair procedures, give special attention to the following safety and operating precautions.

WARNING: **OBSERVE SAFETY PRECAUTIONS DESIGNATED IN SECTION 1.3.**

DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH GENEROUS AMOUNTS OF CLEAN WATER.

ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND CLEANING SOLUTIONS.

IF THE REPAIR IS IN A FUEL TANK AREA THE FUEL TANK PRESSURE SHALL BE RELIEVED PRIOR TO STARTING THE REPAIR. OBSERVE OTHER PRECAUTIONARY PROCEDURES AS DESIGNATED BY THE SAFETY OFFICER.

The following list identifies the assorted materials and miscellaneous equipment that are required to repair typical edge closure damage on honeycomb sandwich panel assemblies. Refer to section 4.2 for specific materials identification. Refer to section 8.0 for more detailed information concerning tools and equipment.

Materials

Adhesive, core splice foam
Adhesive, film
Adhesive, paste
Aluminum honeycomb core
Aluminum sheet
Cheesecloth, bleached, 4-ply pads
Chromate conversion coating
Cleaner, alkaline
Cloth, bleeder
Cloth, fiberglass, 181 fabric
Cloth, rumple, purified polishing fabric
Film, release
Film, vacuum bagging
Paint, finish
Paper, wrapping, wax-free
Phenolic sheet, 0.125-inch
Potting compound, core and dent filler
Primer, adhesive
Primer, sealant, aerodynamic smoother
Putty, vacuum seal
Sealant, aerodynamic smoother
Solution, surface preparation
Solvent, nonchlorinated (for titanium)
Solvent, cleaning
Tape, aluminum foil 0.004 (for aluminum)
Tape, double-backed
Tape, lead foil (for titanium)
Tape, masking, hi-temp
Tape, plastic film, nylon
Titanium, sheet
Water, distilled or demineralized

Tools or Equipment

Abrasive pads, nonwoven, nylon
Abrasive cloth or paper, wet or dry, 180, 220, 320, and 400 grit, aluminum oxide
Aspirator, vacuum
Air supply, 90 to 200 psi (w/pressure regulator, filter, and oil trap)

Blanket, insulation
Blanket, heater, electric
Brush, acid, 3/8- by 1-inch
Brush, paint, short bristle, 1-1/2-inch
Clamps, C-type
Containers, mixing, polyethylene
Controller, electrical, Variac or power stat, adjustable, ac
Drill motor, pneumatic or electric (explosionproof in fuel areas)
Emery cloth, 150, 320, and 400 grit, aluminum oxide (for titanium)
Fillet gun, sealant
Gage, air pressure, 100 psi
Gage, vacuum, 32 in. Hg
Gloves, heat insulating
Gloves, white, cotton fiber
Gloves, rubber or neoprene, surgeons'
Heat lamps, 200 to 350 watt (explosionproof)
Hose, vacuum w/fittings
Knife, core cutting
Knife, putty
Knife, pocket
Micrometer, depth
Micro stop, drill
Pen, ink marking
Power supply, 115 volt, 60 cycle, ac
Pressure plate, 0.125- and 0.250-inch aluminum
Probes, vacuum, connector
Pyrometer, 0^{o} to 400^{o} F, automatic recording
Router bits, assorted sizes
Router motor, pneumatic or electric (explosionproof for fuel areas)
Router templates
Safety glasses or shield
Saw, reciprocating, pneumatic or electric (explosionproof for fuel areas)
Scribe
Spatula, wood or metal
Tin snips, metal cutting
Vacuum cleaner, industrial or hand-type
Vacuum source
Wire, thermocouple, type J or equivalent

6.7.1 EDGE CLOSURE REPAIR PROCEDURE

This repair method is applicable to the type of panel edge treatment shown in figure 6-38. The doubler against the exterior skin may be bonded, machined, or have a chem-milled step. In either of the latter cases, an equivalent build-up of the area with bonded doublers for the repair is usually expedient and adequate.

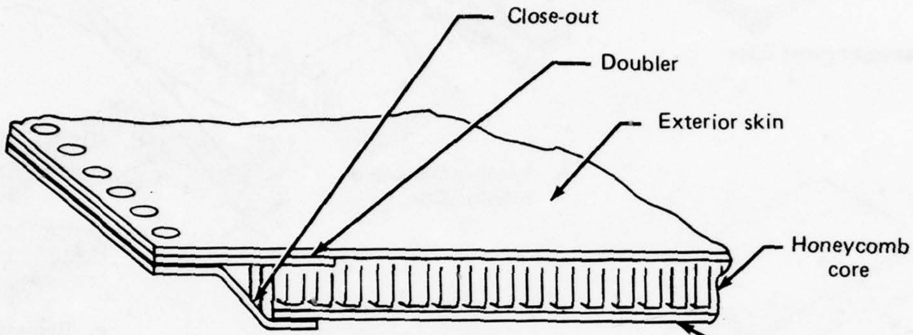


Figure 6-38.—Typical Edge Close-Out

The steps for the repair of this type edge configuration are as follows:

1. Inspect the damaged area closely to determine the damage boundary. Damage assessment methods are discussed in section 2.0.

2. Lay out a cutting pattern for the area where the damaged material is to be removed. The material removal pattern and the general repair sequence is shown in figure 6-39.

   Remove material to a minimum of 0.250 inch beyond the edge of the damage to ensure that all the damage has been included. Allowances should be made for adequate splice overlaps. This should be a minimum of 1.0 inch or as specified by the responsible maintenance engineer.

3. If a standard size router template is not available and it is necessary to fabricate special templates (see instructions outlined in sec. 8.1.1).

4. Position the router template on the panel and hold in place with double-backed tape as shown in figure 6-40.

   NOTE: C-clamps may be used at the panel laminated outer edge. Protect the aluminum surface by inserting an aluminum strip between the C-clamp anvil and the panel surface.

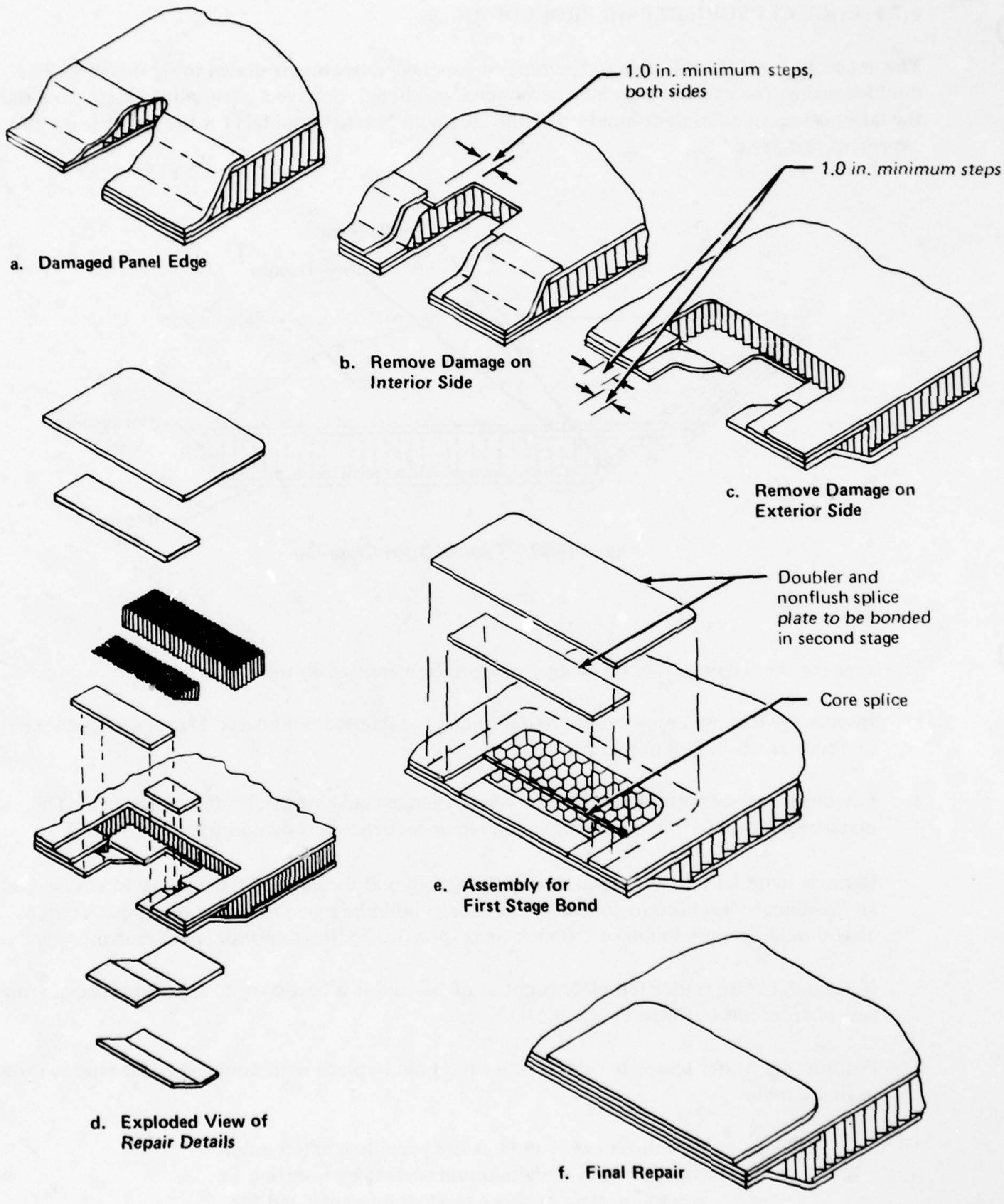


Figure 6-39.—Edge Repair With External Nonflush Patch Plate

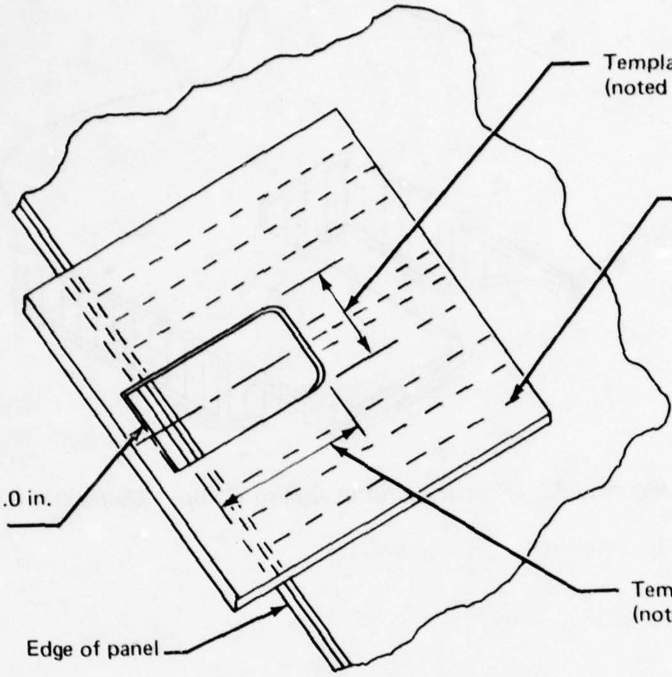


Figure 6-40. –Application of Router Template to Repair Area

5. Using a suitable electric or air-operated routing tool and cutter, remove the material from the damaged area. Necessary precautions should be taken to avoid extending the damage during this operation. This is especially a problem when the panel is bonded with a high temperature adhesive system that has low delamination resistance. Do not remove the previously cured adhesive from the metal surface. The adhesive, if it has not been damaged by moisture, provides an excellent surface for bonding the replacement material.

   WARNING: WEAR AN EYE PROTECTION DEVICE DURING ANY METAL CUTTING OR ROUTING OPERATION.

6. Remove the routing tool and prepare the router template for rework for next router cut. Figure 6-41 shows the finished primary cutout.

7. Reposition the reworked router template, centering it over the primary cutout (see fig. 6-42). Hold in place with double-backed tape and C clamps. Observe the note for eye protection.

8. Reset the router bit to the outer skin thickness to cut the skin only–DO NOT cut into edge doubler.

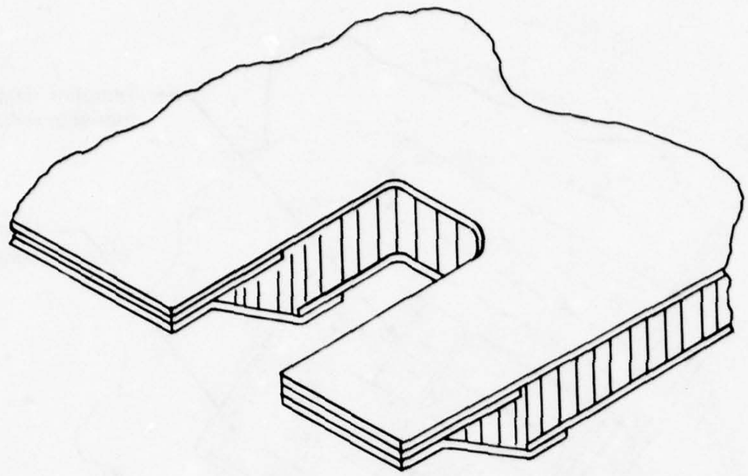


Figure 6-41. -Primary Router Cut to Remove Damage

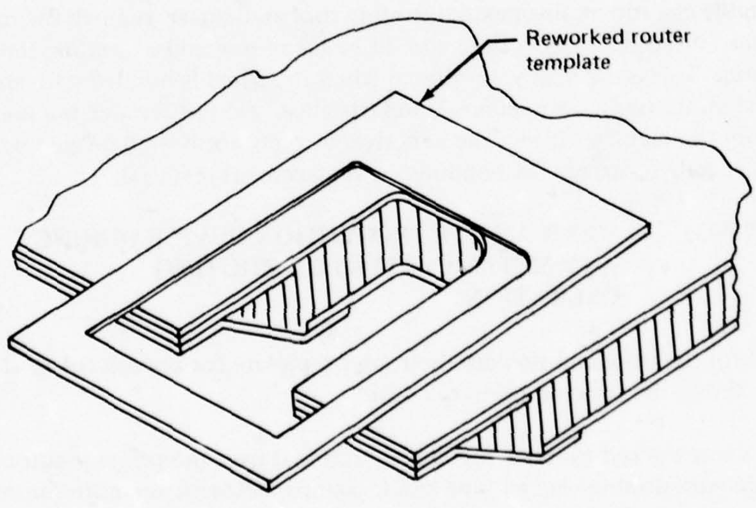


Figure 6-42. -Secondary Router Cut to Remove Outer Skin

9. Reposition the router motor on the template, follow the pattern, and cut through the outer skin. Remove skin (see note).

NOTE: It may be necessary to lower the adhesive peel strength by application of carbon dioxide (dry ice).

10. Fabricate two pieces of 1/8- x 1-inch aluminum strips to act as spacers and locate them next to the router edge. See figure 6-43. Use double-backed tape to hold the spacers in position.

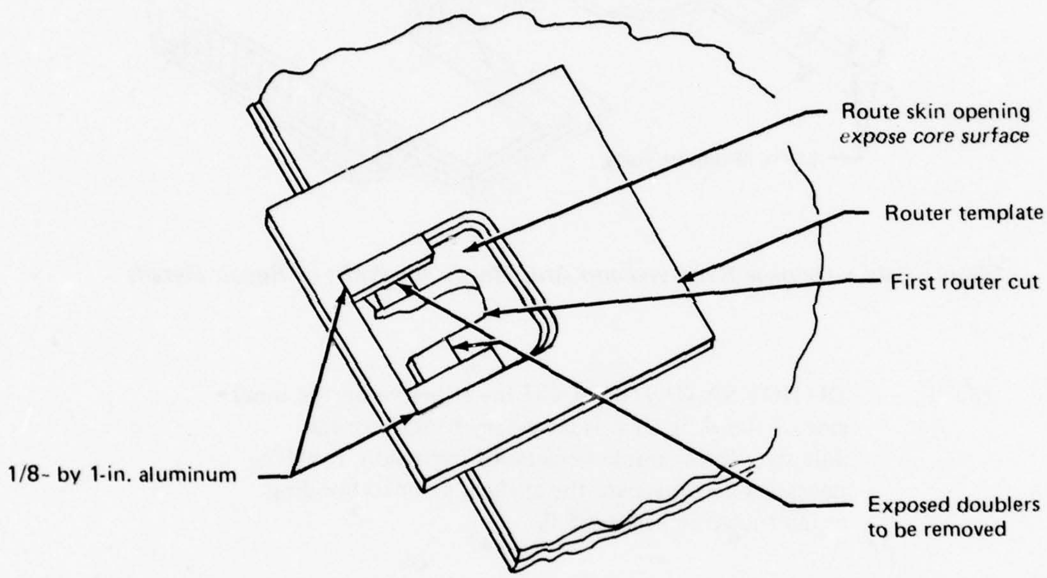


Figure 6-43. -Layout for Router Removal of Edge Doublers

11. Reset the router depth to the skin-plus-doubler thickness. Setting the router bit next to the spacers, route a cut through the doubler width in two places.

12. Remove the routing tool and template.

13. Using a thin blade putty knife, remove the two short ends of the edge doubler, exposing the skin surface. When core material is removed, leave the two small tips under the remaining edge doubler (see fig. 6-44).

14. Use a 220- and 320-grit aluminum oxide, mechanical-locking sanding disk and an air motor to remove the remaining honeycomb core and loose adhesive from the inner side of the sandwich skins. Smooth the metal surfaces having residual adhesive with fine abrasive paper (400-grit, wet or dry, aluminum oxide) or nylon abrasive pads.

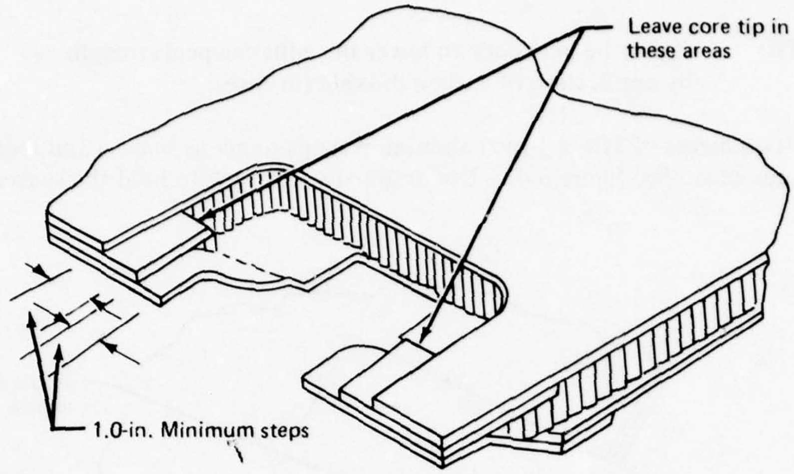


Figure 6-44. –Damage Removed and Area Ready for Prefit of Repair Details

NOTE: DO NOT SAND THROUGH the adhesive on the inner side of the skin. If it is necessary to remove the adhesive, for example because of corrosion, it will be necessary to reprepare the surface prior to bonding as instructed in section 5.0.

15. Use air pressure or vacuum to remove dust or debris from the repair area. Inspect for internal corrosion or moisture.

NOTE: IF MOISTURE OR CORROSION IS PRESENT, ITS EXTENT MUST BE DETERMINED AND IT MUST BE REMOVED.

IF THE REPAIR AREA IS CONTAMINATED WITH FUEL OR HYDRAULIC FLUID, USE MEK OR ANOTHER SUITABLE SOLVENT AND A BRUSH TO CLEAN. BE SURE THE AREA IS FREE OF CONTAMINATION AND DRY BEFORE PROCEEDING WITH THE REPAIR.

16. Fabricate the patch plates:

   a. Select the material to be the same as the sandwich face and doubler material that is being replaced. The gage of each detail should be equivalent to the gage of the piece that is being patched or spliced.

b. Cut the patch or splice details to be of sufficient size to allow for adequate splice overlap. This should be a minimum of 1.0 inch or as specified in the applicable aircraft T.O. Form patch plates to the necessary contour as required.

c. If the nonflush patch plate on the panel interior or exterior exceeds 0.025 inch in thickness, bevel the edge of one side as shown in figure 6-45.

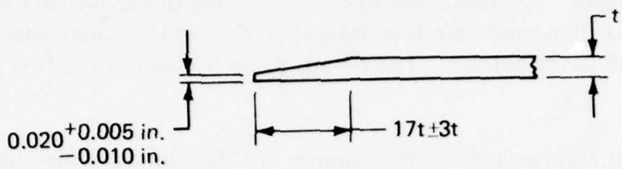


Figure 6-45. -Beveled Edge of Patch Plate

17. Fabricate the core plug:

a. Select the core density, cell size, and alloy to be the same as that used in the original construction. Aluminum honeycomb core shall be a corrosion-resistant nonperforated type. Instructions for cutting the core details are given in section 6.1.2.

b. Cut the core details with the ribbon direction oriented in the same direction as the core in the panel. Trim the edges of the core to fit loosely in the core cavity.

18. Assemble the details and check for proper fit.

19. Clean the core details per section 5.2.

- Use trichloroethane or another suitable solvent for aluminum core.
- Use caution while handling the core plug.
- Play air over the plug until all odor of cleaning solvent is removed. DO NOT damage the cell walls with an air blast. It is acceptable to carefully shake the core plug to remove the solvent.

CAUTION: Clean White Cotton Lintless Gloves Shall Be Worn When Handling Clean Details or Adhesive.

20. Prepare the adhesive:

a. Select the appropriate adhesive film per section 4.2. Observe precautionary notes when removing refrigerated material from storage (sec. 1.2.5). Do not touch the adhesive with bare hands.

b. Cut the required adhesive patches to size. The metal patch details may be used as cutting templates.

21. Clean the repair cavity using cheesecloth dampened with solvent. Do not use excess solvent. Air dry the area for a minimum of 15 minutes at room temperature.

22. Because of the number of details involved in this repair, it is recommended that the bond be accomplished in two stages. The first stage involves bonding of the bottom metal details and the core. The interior of the repair can then be inspected and the core surface sanded flush before bonding the final cover patches. The details to be bonded in the first stage cure are shown in figure 6-39.

a. Identify the bare metal surfaces on the component that will be adhesively bonded during the first bond cycle. Use polyester or aluminum foil tape for aluminum or lead foil or polyester tape for titanium to mask around these areas. Take special care in masking all existing adhesive bondlines and the core area to prevent contamination from the surface preparation solutions or gels.

WARNING: **DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH GENEROUS AMOUNTS OF CLEAN WATER.**

ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND SOLUTIONS.

CAUTION: **Once the Cleaning Procedure Starts, DO NOT Touch With Bare Hands or Contaminate Any Surface to Be Filled, Coated, or Bonded.**

DO NOT Allow the Surface Preparation Solution to Enter the Assembly or Contact Any Previously Cured Adhesive.

Observe Requirements for a Clean Environment.

b. Prepare the bond surfaces of the panel and the sheet metal details per instruction in section 5.0.

c. Rinse the surfaces thoroughly with clean water. Litmus paper should be used to ensure that all trace of acid has been removed. Air dry the surface.

d. Remove masking tape.

23. Apply an adhesive-compatible primer to the bond surfaces. See section 4.2 for primer selection and section 4.3.1 for application instructions. Air dry or bake the primer as instructed.

24. Assemble the details for the initial cure cycle. Figure 6-39 shows an exploded view of the repair details.

    a. Obtain the previously cut adhesive film pieces from storage. Observe precautionary notes regarding conditioning of refrigerated materials, (sec. 1.2.5).

    b. Assemble the lower metal details with interleaving adhesive film.

    c. Obtain the core splice adhesive from storage. See section 4.2 for material selection and section 4.3 for processing instructions.

    d. Position a layer of core splice adhesive against the edge of the existing core.

    e. Fit the nontapered piece of core in place. Position a layer of core splice adhesive against its exposed edge. Position the second piece of core in place.

    The assembly should now be ready for the first stage cure.

25. Place a layer of release film over the part. The metal details that are not being bonded in the first stage cure may be used as caul plates to hold the assembly in position. Using the standard bonding procedure described in section 7.11.1, vacuum bag the repair area and cure per requirements in table 4-3.

    NOTE: For assurance of a quality bond, heat must be applied to BOTH surfaces of the sandwich when the assembly is thicker than 1/2 inch.

26. After the cure has been completed, debag the assembly.

    WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT TOOLS OR PARTS.

27. Inspect the core edges for a homogeneous bond. If voids appear in the bondline, fill with additional core splice foam adhesive. This may be cured at the recommended temperature using heat lamps.

28. Sand the core surface flush with the skin surface. Remove the sanding debris with clean dry compressed air or vacuum.

29. Wipe the surface of the core with cheesecloth moistened with cleaning solvent (refer to section 5.2. Dry to remove all trace of solvent.

30. Mask the core and bondlines to prevent contamination during preparation of the skin surface for bonding the cover plates. Use polyester or aluminum foil tape for aluminum or polyester or lead foil tape for titanium. The skin edges may be overlapped by 0.060 ± 0.020 inch in the area adjacent to the core. Refer to figure 6-36.

31. Chemically prepare the skin surface and the surfaces of the cover patch plates for bonding per instructions in section 5.3. Observe notes regarding cleanliness and safety as noted previously in step 22.

32. After the surface preparation is complete, apply the appropriate adhesive primer per section 4.3.1.

33. Apply adhesive per section 4.3.2 and install the cover patch plates as follows:

    a. Remove the previously cut pieces of adhesive film from storage. Observe precautionary notes regarding conditioning of refrigerated material (sec. 1.2.5).

    b. Remove the separator film from the adhesive and apply adhesive and cover plates.

    c. Secure the cover plates in position with polyester or nylon film tape.

    d. Locate and secure a minimum of these thermocouples around the repair area.

34. Prepare the repair for bonding in accordance with section 7.11.

35. Cure the repair assembly per requirements for the selected adhesive system in section 4.2.

36. Remove the bonding equipment after the cure cycle is complete.

    WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT PARTS OR EQUIPMENT.

37. Remove excess adhesive flash per section 7.12.

38. Inspect the panel per section 10. to ensure that the repair quality is adequate.

39. Seal around the edge of the cover plates with sealing compound (refer to sec. 4.3.6).

40. Apply finish per section 4.3.7 and applicable aircraft T.O.

6.8 WEDGE SECTION TRAILING-EDGE DAMAGE

These methods apply to the repair of wedge-shaped sandwich construction that is typical at the trailing edges of wing or empennage structure. The repairs are for relatively minor damage and are subject to size and weight restrictions imposed by the specific aircraft model's technical orders. Special care should be taken to define the damage boundary. Damage assessment procedures are covered in section 2.0 and non-destructive inspection methods in section 10.0. When the extent of damage is beyond the scope of the small area repair, repair or rebuilding shall be per the techniques outlined in section 7.0.

Repair procedures are presented for three design configurations. These are (1) arrowhead close-out, (2) laminated edge close-out, and (3) the wrap-around skin close-out. The procedures are for aluminum or titanium assemblies. Refer to the applicable aircraft T.O. for repair of fiberglass components.

During the repair activity, give special attention to the following items:

WARNING: **OBSERVE ALL LOCAL SAFETY PRECAUTIONS AND THOSE DESIGNATED IN SECTION 1.3.**

DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH GENEROUS AMOUNTS OF CLEAN WATER.

ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND CLEANING SOLUTIONS.

IF THE REPAIR IS IN A FUEL TANK AREA, THE FUEL TANK PRESSURE SHALL BE RELIEVED PRIOR TO STARTING REPAIR. OBSERVE OTHER PRECAUTIONARY PROCEDURES AS DESIGNATED BY THE SAFETY OFFICER.

CAUTION: **Once the Cleaning Procedure Starts, DO NOT TOUCH or Contaminate Any Surface to Be Filled, Coated, or Bonded.**

DO NOT Allow Solutions to Enter the Assembly or Contact the Previously Cured Adhesive.

Observe Requirements for a Clean Environment.

The following lists identify the assorted expendable materials and miscellaneous equipment that are required to repair various types of trailing edge damage. Refer to sections 4.0 and 5.0, *respectively*, for specific materials identification and surface preparation procedures. Refer to section 8.0 for more detailed information concerning tools and equipment.

Materials

Adhesive, core splice foam
Adhesive, film
Adhesive paste
Aluminum honeycomb core
Aluminum sheet
Cheesecloth, bleached, 4-ply pads
Chromate conversion coating
Cleaner, alkaline
Cloth, bleeder
Cloth, rumple, purified polishing fabric
Film, release
Film, vacuum bagging
Paint, finish
Paper, wrapping, wax-free
Phenolic sheet, 0.125-inch
Potting compound, core and dent filler
Primer, adhesive
Primer, sealant, aerodynamic smoother
Putty, vacuum seal
Sealant, aerodynamic smoother
Solution, surface preparation
Solvent, nonchlorinated (for titanium)
Solvent, cleaning
Tape, aluminum foil 0.004 (for aluminum)
Tape, double-backed
Tape, lead foil (for titanium)
Tape, masking, hi-temp
Tape, plastic film, nylon
Titanium, sheet
Water, distilled or demineralized

Tools or equipment

Abrasive pads, nonwoven, nylon
Abrasive cloth or paper, wet or dry, 180, 220, 320, and 400 grit, aluminum oxide
Aspirator, vacuum
Air supply, 90 to 100 psi (w/pressure regulator, filter, and oil trap)
Blanket, insulation
Blanket, heater, electric

Brush, acid, 3/8- by 1-inch
Brush, paint, short bristle, 1-1/2-inch
Clamps, C-type
Containers, mixing, polyethylene
Controller, electrical, Variac or power stat, adjustable, ac
Drill motor, pneumatic or electric (explosionproof in fuel areas)
Emery cloth, 150, 320, and 400 grit, aluminum oxide (for titanium)
Fillet gun, sealant
Gage, air pressure, 100 psi
Gage, vacuum, 32 in. Hg
Gloves, heat insulating
Gloves, white cotton fiber
Gloves, rubber or neoprene, surgeons'
Heat lamps, 200 to 350 watt (explosionproof)
Hole saw assembly
Hose, vacuum w/fittings
Knife, core cutting
Knife, putty
Knife, pocket
Micrometer, depth
Micro stop, drill
Pen, ink marking
Power supply, 115 volt, 60 cycle, ac
Pressure plate, 0.125- and 0.250-inch aluminum
Probes, vacuum, connector
Pyrometer, 0^{o} to 400^{o} F, automatic recording
Router bits, assorted sizes
Router motor, pneumatic or electric (explosionproof for fuel areas)
Router templates
Safety glasses or shield
Saw, reciprocating, pneumatic or electric (explosionproof for fuel areas)
Scribe
Spatula, wood or metal
Tin snips, metal cutting
Vacuum cleaner, industrial or hand-type
Vacuum source
Wire, thermocouple, type J or equivalent

6.8.1 ARROWHEAD TRAILING-EDGE REPAIR

The method outlined below covers minor repairs to trailing-edge structure having an arrowhead-type close-out. Typical damage of this type is shown in figure 6-46.

The repair steps are as follows:

1. Apply masking around the repair area to prevent further damage during rework and to contain surface preparation chemicals. Use aluminum foil or polyester tape for aluminum and lead foil or polyester tape for titanium.

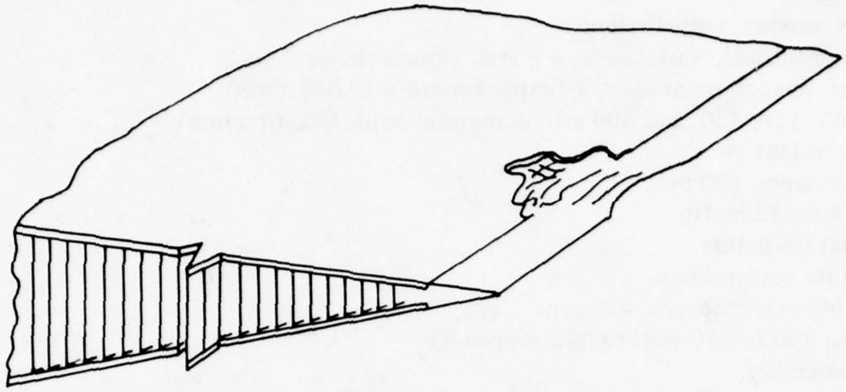


Figure 6-46. –Typical Damage to Arrowhead-Type Trailing-Edge Close-Out

2. Define the boundary of the damaged area. Layout a regular-shaped cutting pattern that extends a minimum of 0.25 inch beyond the damage edge. See figure 6-47.

3. Removal of the damaged area may be facilitated by the use of a router template. If a standard template is not available, fabricate a template from 0.125-inch-thick phenolic or aluminum sheet as instructed in section 8.1.1.

4. Attach the router template over the damaged area with double-backed tape. Allow for the set-back distance required for the router collar.

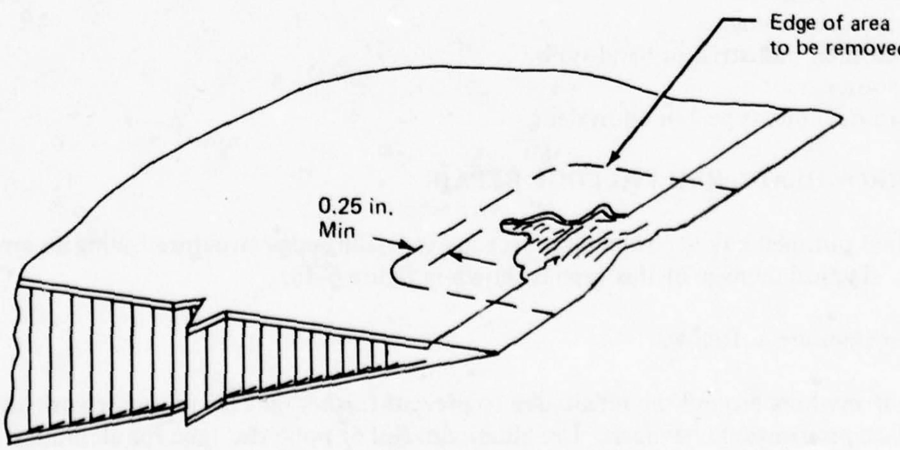


Figure 6-47. -Layout of Cutting Pattern for Damage Removal

5. Using the router per instructions in section 8.1.1, set the router bit to the skin depth and remove the section of damaged skin.

> CAUTION: **Care Must Be Taken While Removing the Damaged Material to Prevent Skin Delamination In the Adjacent Area.**

6. Remove the template and attach it to the opposite side of the panel. Repeat the previous operation to remove the opposing skin section.

7. Using a reciprocating saw or other suitable cutting device, remove the damaged section of the arrowhead. See figure 6-48.

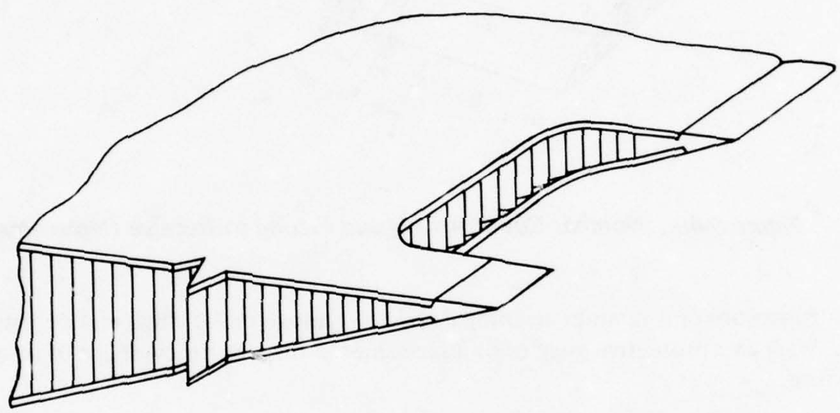


Figure 6-48. -Trailing Edge With Damaged Area Removed

> NOTE: Padded wedge blocks and C-clamps may be used to apply pressure to the skin adjacent to the cut-out area to prevent delamination. Care must be taken to prevent damage to the sandwich core from excess clamping pressure.

8. Remove the core from the cut-out area with a core-cutting knife.

> NOTE: Steps 5, 6, 7, and 8 can be completed in one operation by using a hand-held router and extended router bit per instructions in section 8.1.

9. Using the reciprocating saw (or alternate device), cut notches in the edges of the arrowhead fitting. These should be approximately 0.50 inch deep by 0.25 inch wide and 5° off the fore-and-aft cut line. See figure 6-49.

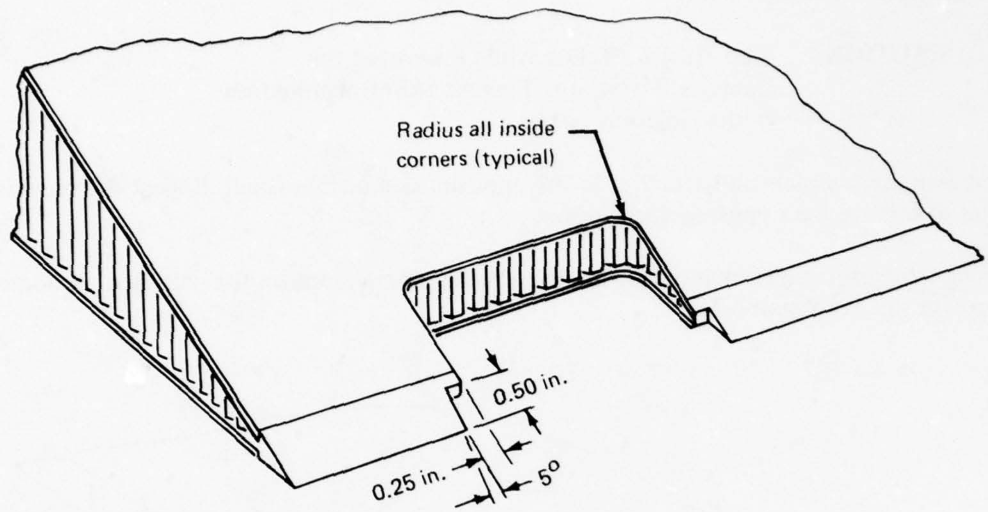


Figure 6-49. –Notches Cut in Arrowhead Fitting to Receive Replacement Part

10. Use air pressure or a vacuum cleaning device to remove metal chips and debris from the cut-out area. Wear eye protective goggles or a face shield. Inspect for evidence of internal corrosion or moisture.

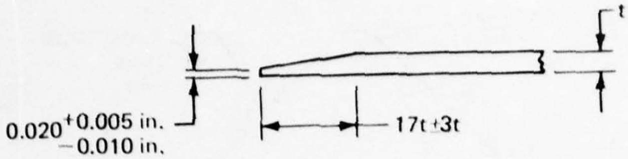
    NOTE: If moisture or corrosion is present, its extent must be determined and it must be removed.

11. Fabricate the repair details. A schematic of the details is shown in figure 6-50. Note that the arrowhead replacement insert does not have the undercuts for the skin.

    a. Select the material for the patch plates to be the same gage, alloy, and temper as that being repaired.

    b. Lay out and cut the two patch plates. The plates must be of sufficient size to allow for a minimum overlap of 1.0 inch or as specified in the applicable aircraft T.O.

    c. If the thickness of the patch plates exceeds 0.025 inch, bevel the edge of one side per the sketch.



Bevel Detail Sketch

12. Fabricate the core plug. Select the core density, cell size, and alloy to be the same as that used in the original construction. Aluminum honeycomb shall be a corrosion-resistant nonperforated type.

    a. Instructions for cutting the core details are given in section 6.1.2. Cut the core details with the foil ribbon direction oriented in the same direction as the core in the panel. The core depth should be such that the core surface is flush with the outer surface of the component skin. Trim the edges of the core to fit loosely in the core cavity.

    NOTE: Use care in handling the core plug to prevent damage.

13. Fabricate the arrowhead replacement insert. Machine a replacement section from a suitable extrusion or bar stock. Match the 5° angle that was cut in the component arrowhead to produce a net fit.

14. Assemble the details and make alterations as required to obtain proper fit.

15. Remove the organic finish around the cavity on both surfaces using 220- to 320-grit aluminum oxide paper or emery cloth. Polish with nylon abrasive pads.

16. Clean the repair cavity using cheesecloth dampened with solvent. Do not use excess solvent.

    CAUTION: **If the Repair Area is Contaminated With Fuel or Hydraulic Fluid, Use MEK or Other Suitable Solvent and a Brush to Clean. Be Sure the Area is Free of Contamination and Dry Before Proceeding With the Repair.**

    Air dry the area for a minimum of 15 minutes at room temperature.

    CAUTION: **Care Should Be Taken Not to Touch the Cleaned Area Except with White Lintless Cotton Gloves.**

17. Identify the bare metal surfaces on each side of the component that will be adhesively bonded during the repair. Use aluminum foil tape (lead foil for titanium) to mask around these areas, as shown in figure [illegible]. Take special precautions to protect the bondlines and the core area to prevent contamination from the cleaning solutions or gels. Edges of the cavity and the bondline may be overlapped [illegible] inch by the tape as illustrated in the figure.

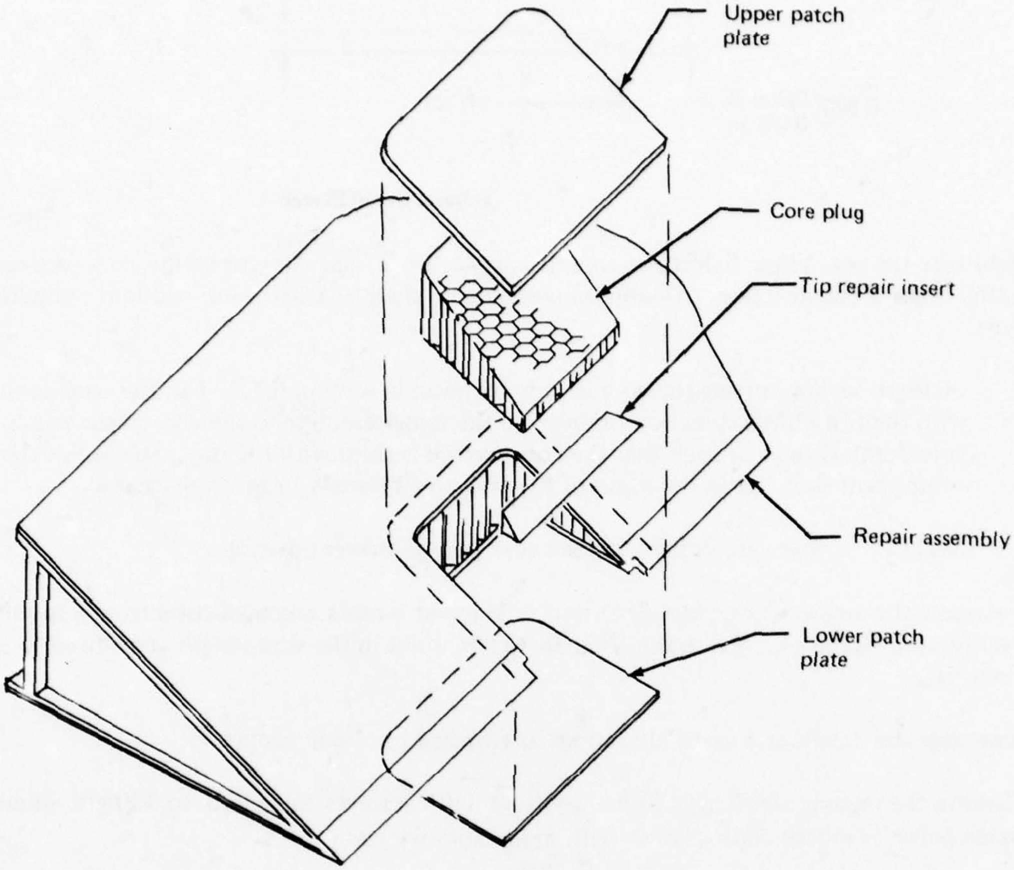


Figure 6-50. —Schematic of Repair for Arrowhead-Type Trailing-Edge Damage

18. Prepare the bond surfaces of the component, the sheet metal patch plates, and the arrowhead replacement part as instructed in section 5.0. Rinse the surfaces thoroughly with clean water. Litmus paper should be used to ensure that all acid has been removed. Air dry the surface.

19. Clean the core detail per section 5.2.

    - Use trichloroethane or other suitable solvents for aluminum core.
    - Use caution while handling the core plug.
    - Play air over the plug until all odor of cleaning solvent is removed. Do not damage the cell walls with an air blast. It is acceptable to carefully shake the core plug to remove the solvent.

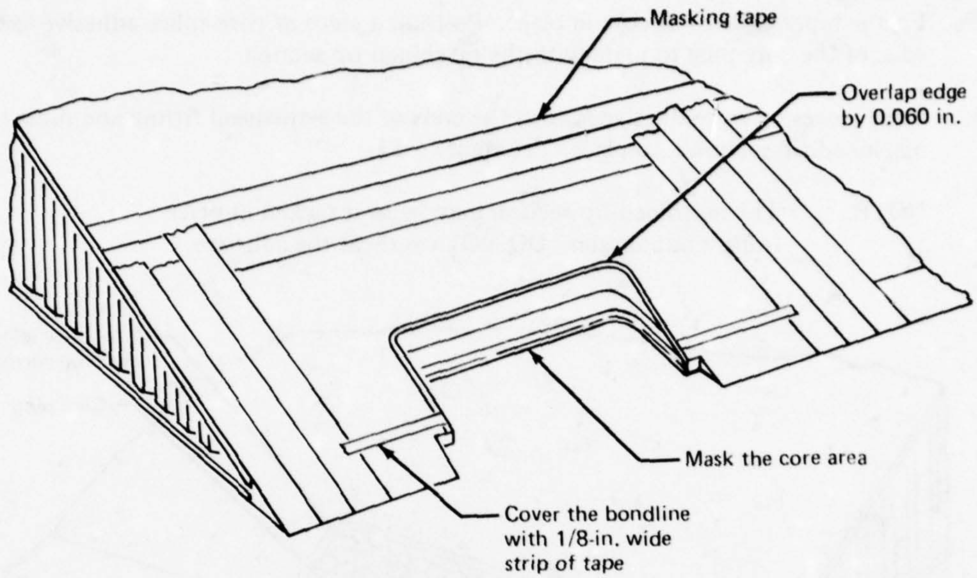


Figure 6-51. –Application of Masking Tape Prior to Surface Cleaning

20. Prepare the adhesive:

    a. Select the appropriate adhesive film and core splice adhesive per section 4.2. Observe precautionary notes when removing refrigerated material from storage (sec. 1.2.5). Do not touch the adhesive with bare hands.

    b. Cut the required adhesive film patches to size. The metal patch plates may be used as cutting templates.

21. Remove masking tape from the repair area.

22. Apply an adhesive-compatible primer to the bond surfaces. See section 4.2 for the primer selection and section 4.3.1 for application instructions. Air dry or bake the primer as instructed.

23. Assemble the repair details for bonding:

    a. Obtain the core splice adhesive from storage. See section 4.2 for material selection. Observe precautions concerning preconditioning of refrigerated materials prior to opening (sec. 1.2.5).

    b. Position a strip of core splice adhesive against the edge of the existing core.

c. Fit the tapered piece of core in place. Position a piece of core splice adhesive against the edge of the core plug to mate with the machined tip section.

d. Place pieces of tape adhesive against the ends of the arrowhead fitting and press the machined tip section into place. See figure 6-52.

NOTE: The machined tip section may be heat tacked in place using a hot air gun. DO NOT overheat the adhesive.

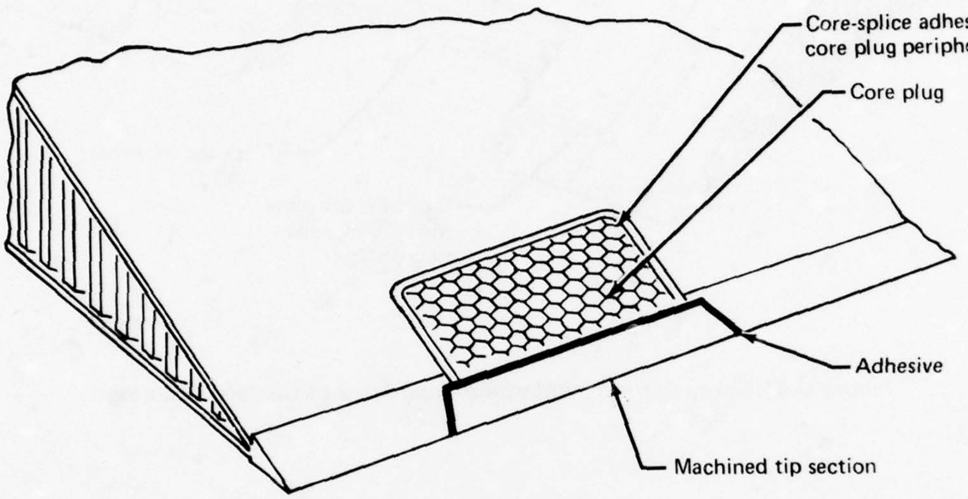


Figure 6-52.—Assembly With Core Plug and Tip Fitting in Place

e. Install the previously cut adhesive film patches and the two metal splice plates. Take special care not to touch the especially prepared bond surfaces. Secure the patch plates in place with nylon tape. The assembly should now be ready for cure.

24. Prepare the assembly for bonding in accordance with section 7.11.

NOTE: Special precautions must be taken to prevent crushing of wedge sections during cure. Use support blocks and caul plates as described in section 9.0.

25. Cure the repair assembly per requirements for the selected adhesive system as noted in section 4.2.

26. Remove the bonding equipment after the cure cycle is complete.

WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT PARTS OR EQUIPMENT.

27. Remove excess adhesive flash (sec. 7.12).

28. Nondestructively inspect the component per instructions in section 10.0 to ensure that the repair quality is satisfactory.

29. Seal around the edges of the cover plates with sealing compound (refer to sec. 4.2 and 4.3.6).

30. Apply finish per section 4.3.7 and the applicable aircraft T.O. The completed repair is shown in figure 6-53.

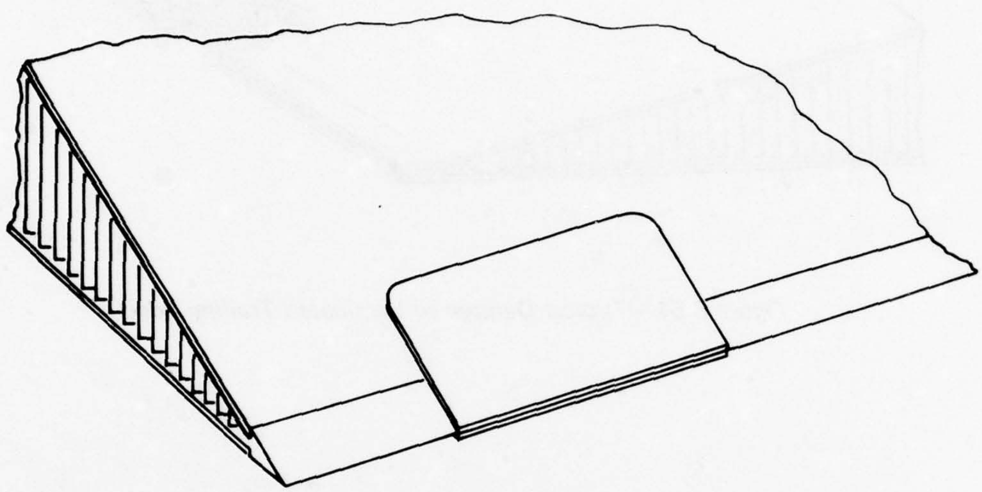


Figure 6-53.—Completed Repair of Arrowhead-Type Trailing Edge

6.8.2 LAMINATED TRAILING-EDGE CLOSEOUT REPAIR

This method covers the repair of minor damage of the type shown in figure 6-54. The edge closure design is laminated metal. The method provides for either a flush repair on one surface or a repair with two nonflush patch plates.

The repair steps are as follows:

1. Apply masking tape around the repair area to prevent further damage during rework and to contain surface preparation chemicals. Use aluminum foil or polyester tape for aluminum and lead foil or polyester tape for titanium.

2. Define the boundary of the damaged area. Lay out a regular-shaped cutting pattern that extends a minimum of 0.25 inch beyond the damage edge. See figure 6-55.

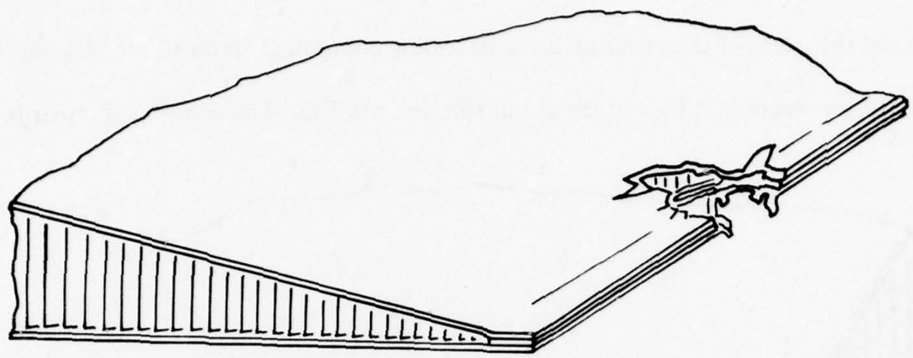


Figure 6-54.—Typical Damage to Laminated Trailing Edge

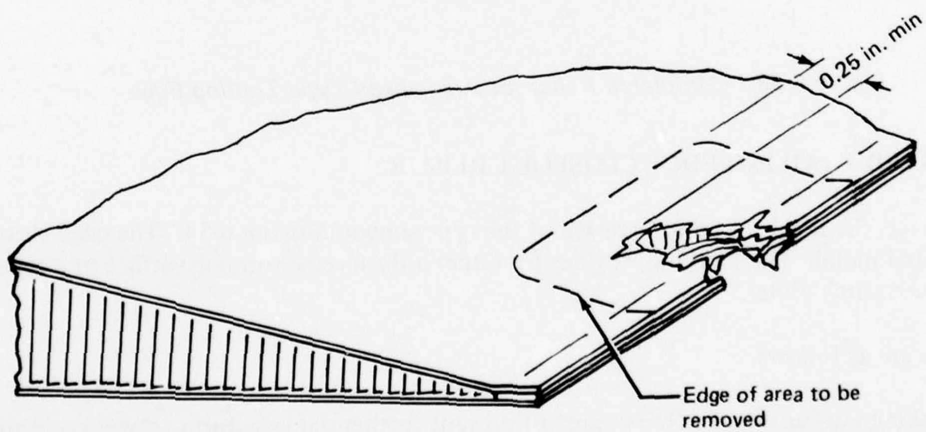
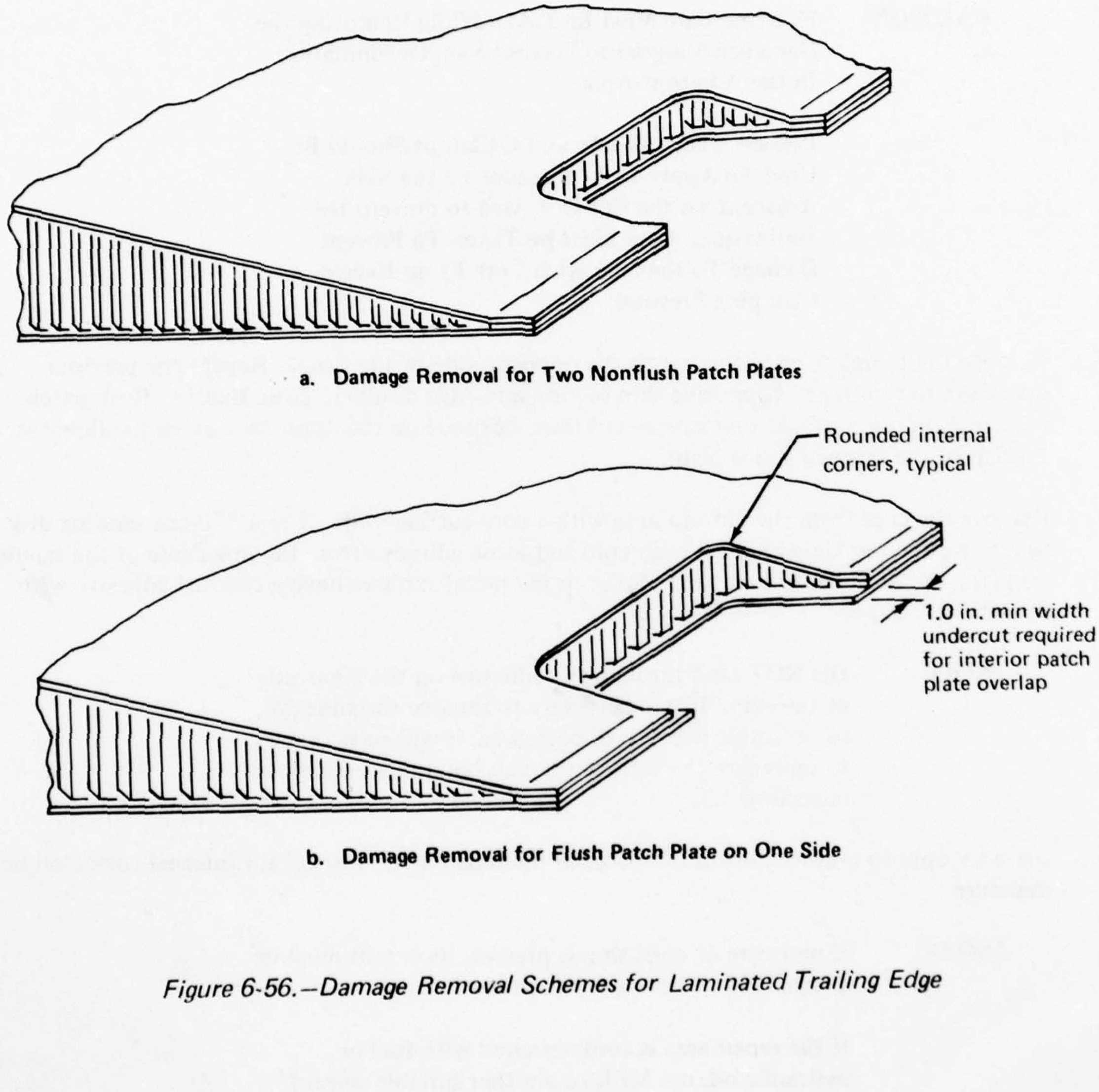


Figure 6-55.—Layout of Damaged Trailing-Edge Area To Be Removed

NOTE: The type of cut used to remove the damage is dependent on whether two nonflush patch plates or a nonflush and a flush patch plate are to be used. Sketches showing the two damage removal schemes are shown in figures 6-56, a and b.



a. **Damage Removal for Two Nonflush Patch Plates**

b. **Damage Removal for Flush Patch Plate on One Side**

Figure 6-56.—Damage Removal Schemes for Laminated Trailing Edge

3. Removal of the damaged area may be facilitated by the use of a router template. If a standard template is not available, a template may be fabricated from 0.125-inch-thick phenolic sheet as instructed in section 8.1.1.

4. Attach the router template over the damaged area with double-backed tape. Allow for the set-back distance required for the router collar.

5. Using the router, per instructions in section 8.1.1, set the router bit to the skin depth and remove the section of damaged skin.

CAUTION: Extreme Care Must Be Taken While Removing the Damaged Material to Prevent Skin Delamination In the Adjacent Area.

Padded Wedge Blocks and C-Clamps Should Be Used To Apply Light Pressure To the Skin Adjacent To the Cut-Out Area to Prevent Delamination. Care Must Be Taken To Prevent Damage To the Sandwich Core From Excess Clamping Pressure.

6. Remove the template and attach it to the opposite side of the panel. Repeat the previous operation to remove the opposing skin section and edge doubler. Note that if a flush patch is desired on one surface, a larger size cut must be made on the opposite surface to allow for overlap of the internal splice plate.

7. Remove the core from the cut-out area with a core-cutting knife. Use a 320-grit sanding disk to remove the remaining honeycomb core and loose adhesive from the inner side of the sandwich skin (for the flush-one-side repair). Smooth the metal surfaces having residual adhesive with fine abrasive paper.

NOTE: DO NOT sand through the adhesive on the inner side of the skin. If it is necessary to remove the adhesive, for example because of corrosion, it will be necessary to reprepare the surface prior to bonding as instructed in section 5.3.

8. Use a vacuum to remove dust or debris from the repair area. Inspect for internal corrosion or moisture.

NOTE: If moisture or corrosion is present, its extent must be determined and it must be removed.

If the repair area is contaminated with fuel or hydraulic oil, use MEK or another suitable solvent and a brush to clean. Be sure the area is free of contamination and dry before proceeding with the repair.

9. Exploded views showing the detailed parts required for the repair are shown in figure 6-57. Fabricate the sheet metal details as follows:

   a. Select the material to be the same as the sandwich face and doubler material that is being replaced. The gage of each detail should be equivalent to the gage of the piece that is being patched or spliced.

   b. Cut the patch or splice details to be of sufficient size to allow for adequate splice overlap. This should be a minimum of 1.0 inch or as specified by the responsible engineering authority. Form patch plates to the necessary contour as required.

   c. If the nonflush patch plate on the panel exterior exceeds 0.025 inch in thickness, bevel the edge of one side as shown in figure 6-58.

10. Fabricate the core plug:

   a. Select the core density, cell size, and alloy to be the same as that used in the original construction. Aluminum honeycomb core shall be a corrosion-resistant nonperforated type. Instructions for cutting the core details are given in section 6.1.2.

   b. Cut the core details with the ribbon direction oriented in the same direction as the core in the panel. Trim the edges of the core to fit loosely in the core cavity.

11. Assemble the details and check for proper fit.

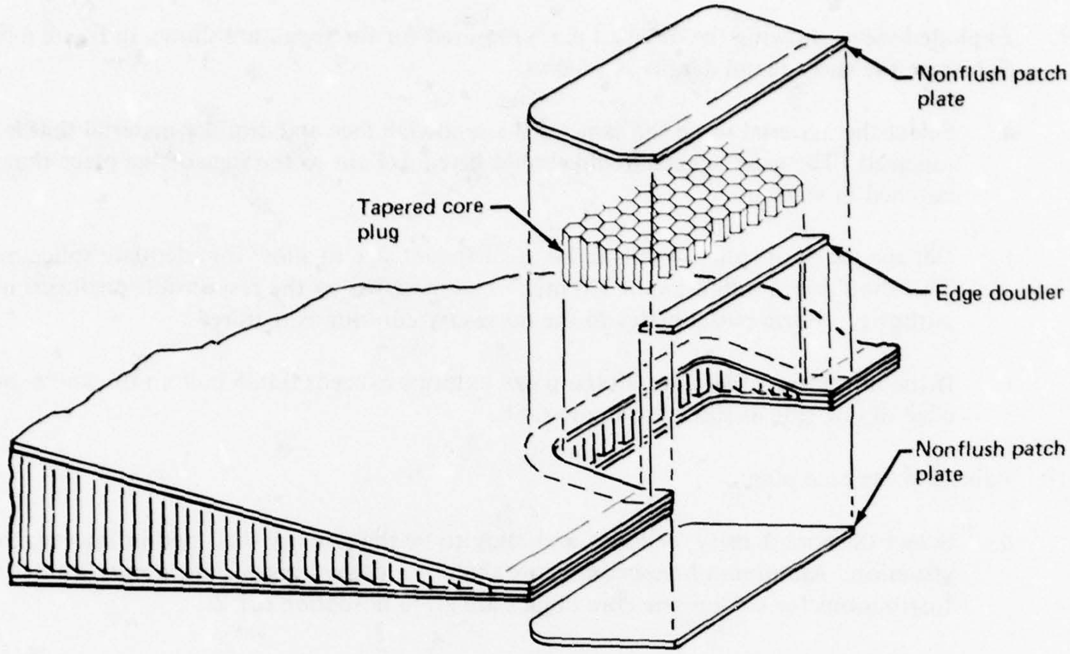
12. Identify the metal surfaces on each side of the component that will be adhesively bonded during the repair. Remove the organic finish from these surfaces using 220- to 320-grit abrasive paper. Polish with nylon abrasive pads.

13. Clean the repair cavity using cheesecloth dampened with solvent. Do not use excess solvent. Air dry the area for a minimum of 15 minutes at room temperature.

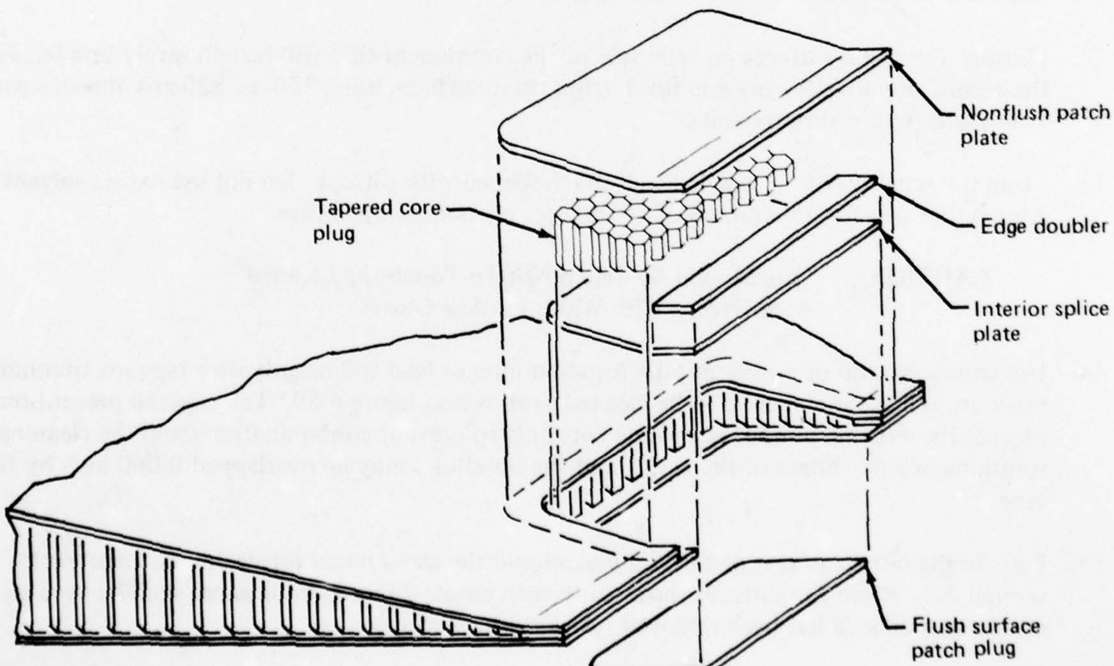
CAUTION: Care Should Be Taken Not To Touch the Cleaned Area Except With White Lintless Gloves.

14. Use aluminum foil or polyester tape for aluminum or lead foil or polyester tape for titanium to mask around the metal areas to be cleaned as shown in figure 6-59. Take special precautions to protect the existing bondlines and the core area to prevent contamination from the cleaning solutions or gels. Edges of the cavity and the bondlines may be overlapped 0.060 inch by the tape.

15. Prepare the bond surfaces of the component and the sheet metal repair details as instructed in section 5.3. Rinse the surfaces thoroughly with clean water. Litmus paper shall be used to ensure that all acid has been removed. Air dry the surface.



a. Repair With Two Nonflush Patch Plates



b. Repair With One Flush Patch

Figure 6-57.—Schematic of Repair for Laminated Trailing-Edge Damage

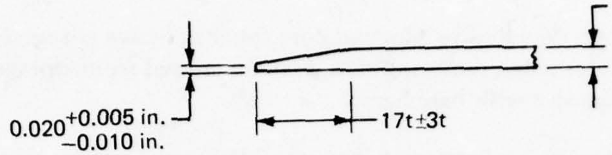


Figure 6-58.—Beveled Edge of Patch Plate

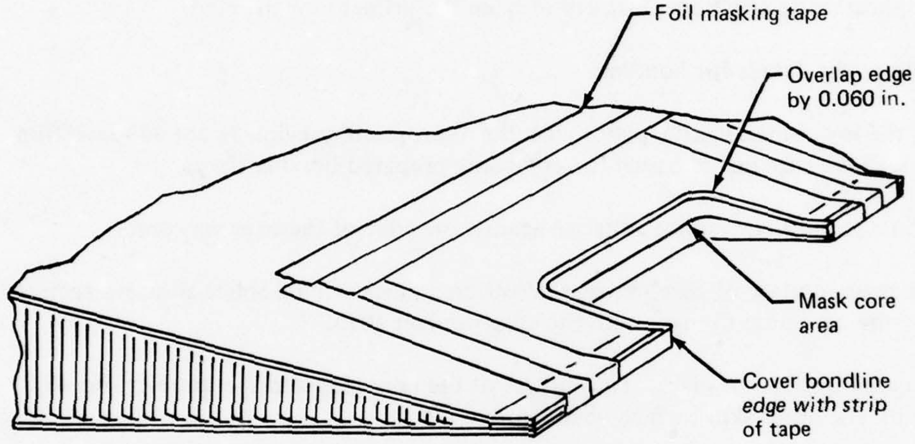


Figure 6-59.—Application of Masking Tape Prior to Surface Cleaning

16. Clean the core detail per section 5.2.

- Use trichloroethane or other suitable solvents for aluminum core. Adhere to local safety requirements.
- Use caution while handling the core plug.
- Carefully shake the core plug to remove the excess solvent. Play air lightly over the plug until all odor of cleaning solvent is removed.

NOTE: Clean white cotton lintless gloves shall be worn when handling clean details or adhesive.

17. Prepare the adhesive:

    a. Select the appropriate adhesive film and core splice adhesive per section 4.2. Observe precautionary notes when removing refrigerated material from storage (sec. 1.2.5). Do not touch the adhesive with bare hands.

    b. Cut the required adhesive film patches to size. The metal patch plates may be used as cutting templates.

18. Remove masking tape from the repair area.

19. Apply an adhesive-compatible primer to the bond surfaces. See section 4.2 for material and 4.3.1 for application instructions. Air dry or bake the primer as instructed.

20. Assemble the repair details for bonding:

    a. Install the lower metal patch plates with the appropriate previously cut adhesive film patches. Take care not to touch the especially prepared bond surfaces.

    b. Position a strip of core splice adhesive against the edge of the existing core.

    c. Fit the tapered piece of core in place. Position a piece of core splice adhesive against the edge of the core plug to mate with the edge doubler strip.

    d. Fit the edge doubler in place. The surface of the core plug and the doubler should be level with the outer skin surface. See figure 6-60.

    e. Install the covering adhesive film and patch plate. Secure the patch plates in place with nylon tape. The assembly should now be ready for cure.

    f. Locate a minimum of three thermocouples around the repair area and fix in place with nylon or polyester tape.

21. Prepare the assembly for bonding in accordance with section 7.11.

    NOTE: Special precautions must be taken to prevent crushing of wedge sections during cure. Use support blocks and caul plates as described in section 9.0.

22. Cure the repair assembly per requirements for the selected adhesive system as noted in section 4.2.

23. Remove the bonding equipment after the cure cycle is complete.

    WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT PARTS OR EQUIPMENT.

24. Remove excess adhesive flash (sec. 7.12).

25. Non-destructively inspect the component to ensure that the repair quality is satisfactory.

26. Seal around the edges of the cover plates with sealing compound (refer to sec. 4.2 and 4.3.6 for material and application instructions).

27. Apply finish per section 4.3.7 and the applicable aircraft T.O. The completed repair is shown in figure 6-61.

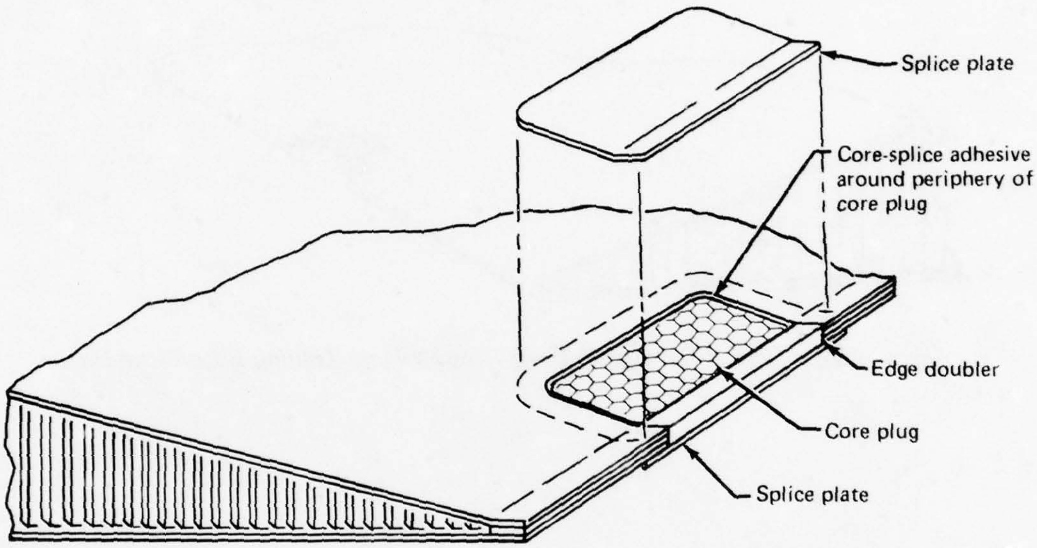


Figure 6-60.—Assembly With Lower Splice Plate, Core Plug, and Edge Doubler in Place

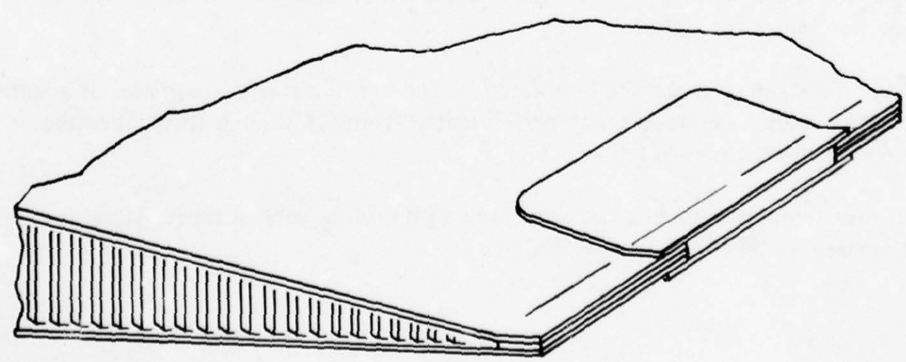


Figure 6-61.—Completed Repair of Laminated Trailing Edge

6.8.3 WRAP-AROUND TRAILING-EDGE REPAIR

This section provides instruction for the repair of minor damage to wrap-around-type trailing edge structure such as is shown in figure 6-62. General notes regarding this repair method are given at the beginning of this section (6.8). Additionally refer to the beginning of this section for precautionary notes and the listing of required repair materials, tools and equipment.

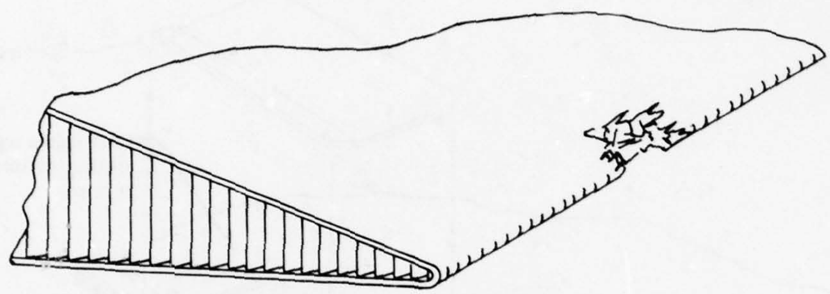


Figure 6-62.—Typical Damage to Wrap-Around-Type Trailing Edge Close-Out

The repair steps are as follows:

1. Define the boundary of the damaged area (applying coordinate lines may be helpful during assembly).

2. Lay out a regular-shaped cutting pattern that extends a minimum of 0.25 inch beyond the damage edge. See figure 6-48 or 6-56.

3. Removal of the damaged area may be facilitated by the use of a router template. If a standard template is not available, a template may be fabricated from 0.125-inch-thick phenolic or aluminum sheet as instructed in section 8.1.1.

4. Attach the router template over the damaged area with double-backed tape. Allow for the set-back distance required for the router collar.

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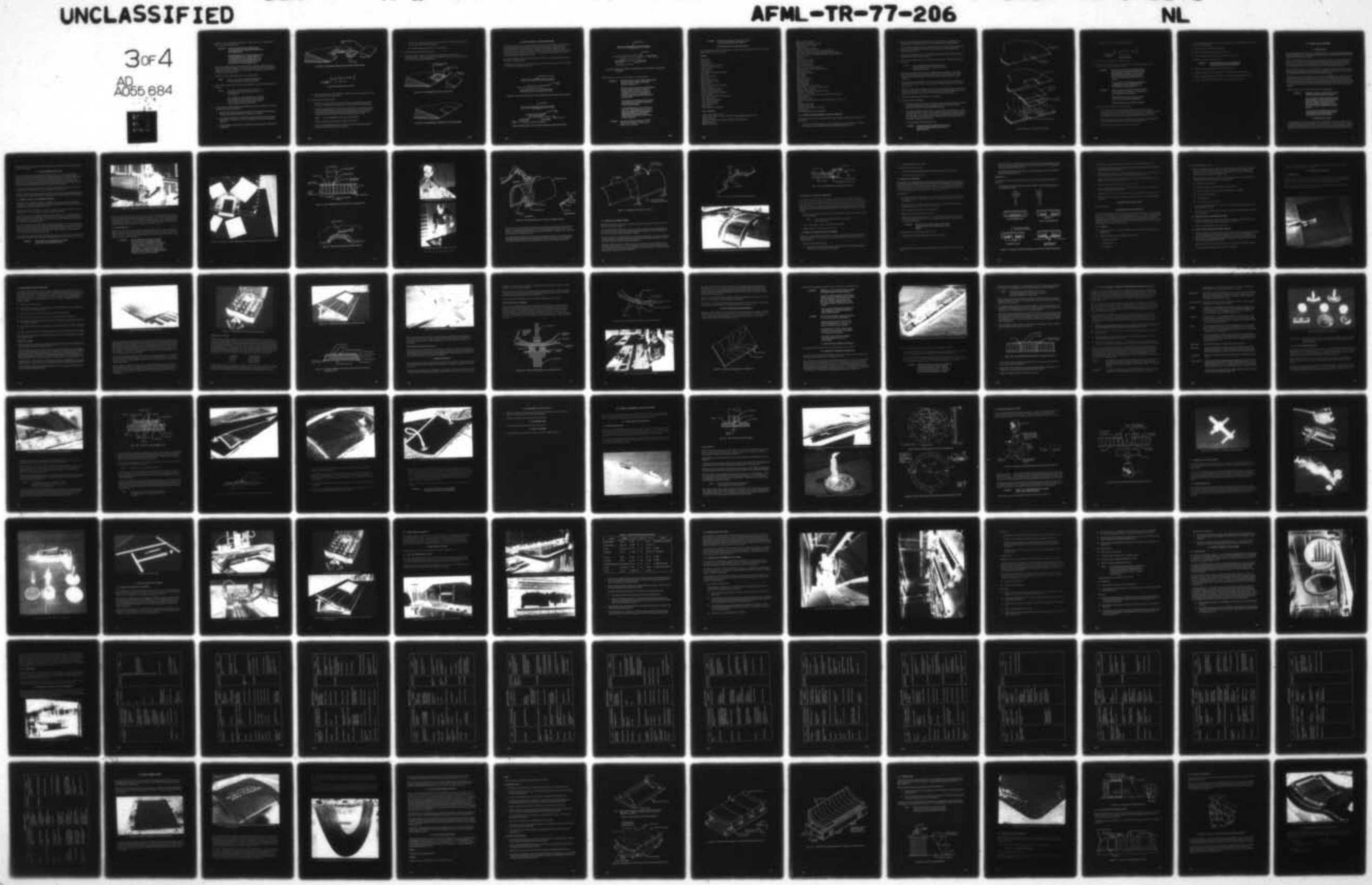

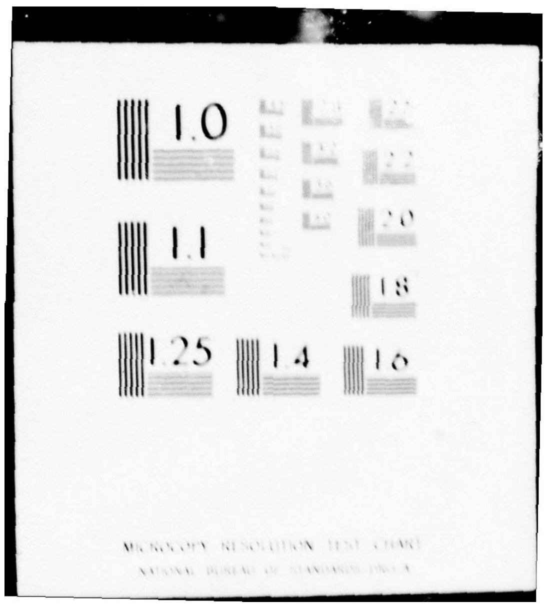
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5. Using the router, per instructions in section 8.1.1, set the router bit to the skin depth and remove the section of damaged skin.

> CAUTION: **Extreme Care Must Be Taken While Removing the Damaged Material To Prevent Skin Delamination In the Adjacent Area.**
>
> **Padded Wedge Blocks and C-Clamps Should Be Used To Apply Light Pressure To the Skin Adjacent To the Cut-Out Area To Prevent Delamination. Care Must Be Taken To Prevent Damage To the Sandwich Core From Excess Clamping Pressure.**

6. Remove the template and attach it to the opposite side of the panel. Repeat the previous operation to remove the opposing skin section and edge doubler. Note that if a flush patch is desired on one surface, a larger size cut must be made on the opposite surface to allow for overlap of the internal splice plate.

7. Remove the core from the cut-out area with a core-cutting knife.

> NOTE: Steps 5, 6, and 7 can be completed in one operation by using a hand-held router and an extended bit.

8. Use a vacuum to remove dust or debris from the repair area. Inspect for internal corrosion or moisture.

> NOTE: If moisture or corrosion is present, its extent must be determined and it must be removed. (See sec. 7.3.5 for instructions.)
>
> If the repair area is contaminated with fuel or hydraulic fluid, use MEK or another suitable solvent, and a brush to clean. Be sure the area is free from contamination and dry before proceeding with the repair.

9. An exploded view of the detailed parts required for repair is shown in figure 6-63. Fabricate the sheet metal patch plate as follows:

   a. Select the material to be the same as the sandwich face material that is being patched. The gage of the patch plate should be the same as that of the skin.

   b. Lay out and cut the patch to be of sufficient size to allow for adequate edge overlap. This should be a minimum of 1.0 inch or as specified by the responsible engineering authority.

   c. If the patch plate exceeds 0.025 inch in thickness, bevel the edge of one side as shown in figure 6-64.

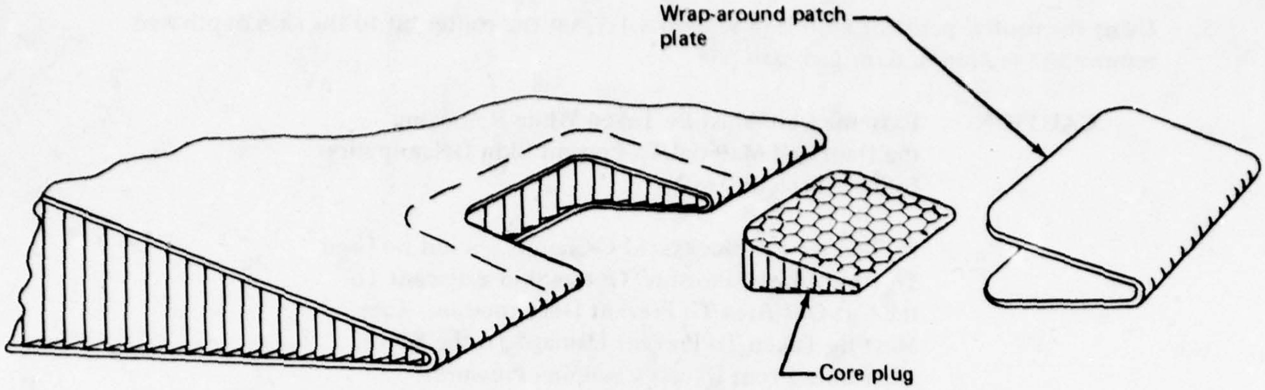


Figure 6-63.—Trailing-Edge Damage Removed and Repair Details Prepared

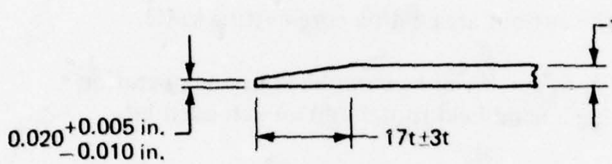


Figure 6-64.—Beveled Edge of Patch Plate

d. Form the patch plate to a radius and angle to match the outer surface trailing-edge contour. Be sure the edge bevel is on the outside.

10. Fabricate the honeycomb core plug:

a. Select the core density, cell size, and alloy to be the same as that used in the original construction. Aluminum honeycomb shall be a corrosion-resistant nonperforated type.

b. Instructions for cutting the core details are given in section 6.1.2. Cut the core details with the foil ribbon direction oriented in the same direction as the core in the panel. The core depth should be such that the core surface is flush with the outer surface of the component skin. Trim the edges of the core to fit loosely in the core cavity.

NOTE: Use care in handling the core plug to prevent damage.

c. Select and prepare a potting compound as noted in section 4.3.4.

d. Fill the core plug trailing edge cells for a width of one inch with the prepared potting material. Cure per the requirements in section 4.2.

e. After the cure is complete, sand the surfaces smooth and radius the trailing edge to match the outer radius of the damaged component.

f. Use a vacuum cleaning device to remove the sanding debris.

11. Assemble the details and check for proper fit.

12. Continue the repair sequence for the laminated trailing-edge repair in section 6.8.2, items 14 through 27. The detail assembly, after installation of the core, is shown in figure 6-65. The completed repair is shown in figure 6-66.

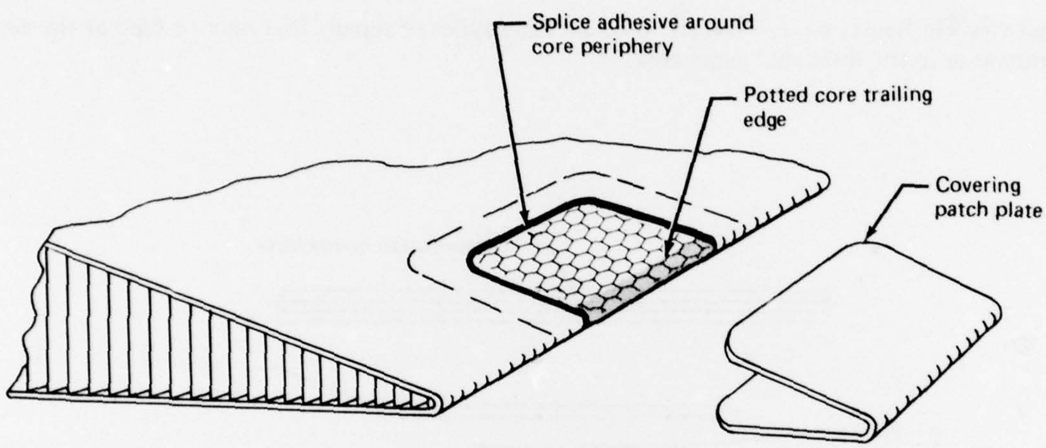


Figure 6-65.—Trailing-Edge Repair With Core Plug in Place

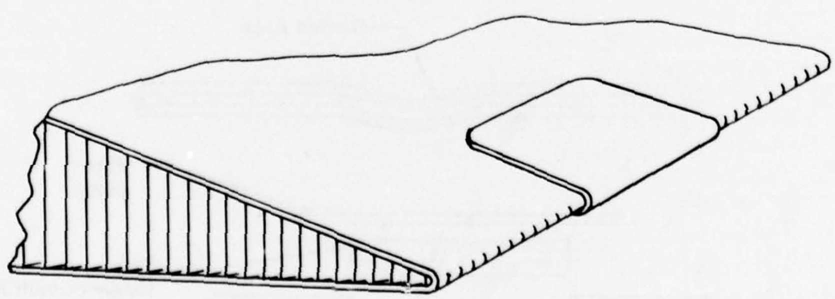


Figure 6-66.—Completed Repair of Wrap-Around—Type Trailing Edge

6.9 METAL-TO-METAL LAMINATED REPAIRS

These repairs are for relatively minor damage and are subject to size and weight restrictions imposed by the applicable aircraft technical orders. Special care should be taken to define the damage boundary, especially if corrosion is the cause of damage to the laminate. Damage assessment procedures are covered in section 2.0 and nondestructive inspection methods in section 10.0. When the extent of damage is major and beyond the scope of small area repairs, consideration should be given to replacing the laminate with a new one.

Procedures are outlined to repair damage inflicted on a two- three-, or four-layered laminate and to either edge or midpanel damage.

Sectional views in figures 6-67, 6-68, and 6-69 indicate types of repairs that may be used at the edge of a laminate or in the midpanel panel area.

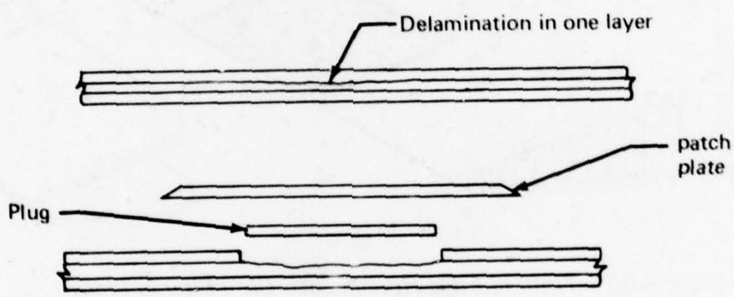


Figure 6-67.—Delamination of Double- or Triple-Layered Laminate and Typical Repair Scheme

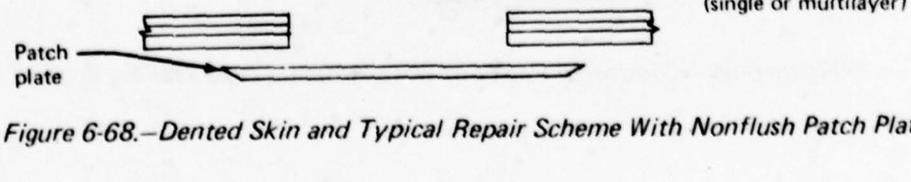


Figure 6-68.—Dented Skin and Typical Repair Scheme With Nonflush Patch Plates

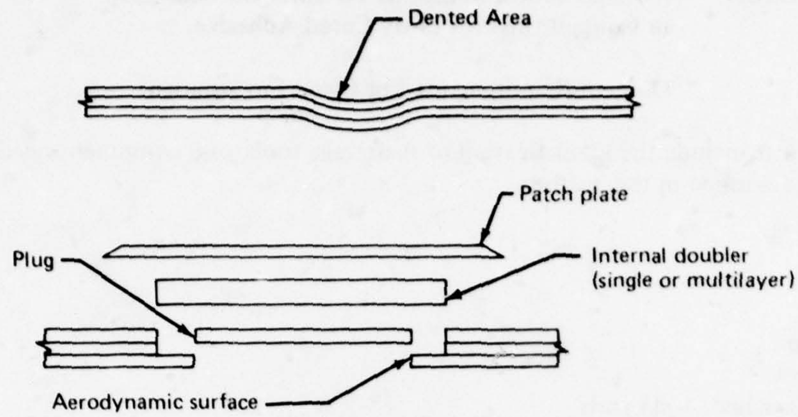


Figure 6-69.—Schematic of Repair for Dented Skin With Typical Repair for Aerodynamic Smoothness

During the repair activity, give special attention to the following items:

WARNING: OBSERVE SAFETY PRECAUTIONS DESIGNATED BY LOCAL REGULATIONS AND THOSE NOTED IN SECTION 1.3.

DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH GENEROUS AMOUNTS OF CLEAN WATER.

ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND SOLUTIONS.

IF THE REPAIR IS IN A FUEL TANK AREA, THE FUEL TANK PRESSURE SHALL BE RELIEVED PRIOR TO STARTING REPAIR. OBSERVE OTHER PRECAUTIONARY PROCEDURES AS DESIGNATED BY THE SAFETY OFFICER.

CAUTION: **Once the Cleaning Procedure Starts, DO NOT TOUCH or Contaminate Any Surface To Be Filled, Coated, or Bonded.**

CAUTION: DO NOT Allow Solutions To Enter the Assembly or Contact the Previously Cured Adhesive.

Observe Requirements For Clean Environment.

The following lists include the identification of materials, tools, and equipment needed for accomplishing the repairs described in this section.

Materials

Adhesive, film
Adhesive, paste
Aluminum sheet
Cheesecloth, bleached, 4-ply pads
Chromate conversion coating
Cleaner, alkaline
Cloth, bleeder
Cloth, rumple, purified polishing fabric
Film, release
Film, vacuum bagging
Paint, finish
Paper, wrapping, wax-free
Phenolic sheet, 0.125-inch
Primer, adhesive
Primer, sealant, aerodynamic smoother
Putty, vacuum seal
Sealant, aerodynamic smoother
Solution, surface preparation
Solvent, nonchlorinated (for titanium)
Solvent, cleaning
Tape, aluminum foil 0.004 (for aluminum)
Tape, double-backed
Tape, lead foil (for titanium)
Tape, masking, hi-temp
Tape, plastic film, nylon
Titanium, sheet
Water, distilled or demineralized

Tools or Equipment

Abrasive pads, nonwoven, nylon
Abrasive cloth or paper, wet or dry, 180, 220, 320, and 400 grit, aluminum oxide
Aspirator, vacuum
Air supply, 90 to 100 psi (w/pressure regulator, filter, and oil trap)
Blanket, insulation
Blanket, heater, electric

Brush, acid, 3/8- by 1-inch
Brush, paint, short bristle, 1-1/2-inch
Burnishing tool, metal or plastic
Clamps, C-type
Containers, mixing, polyethylene
Controller, electrical, Variac or power stat, adjustable, ac
Drill motor, pneumatic or electric (explosionproof in fuel areas)
Emery cloth, 150, 320, and 400 grit, aluminum oxide (for titanium)
Fillet gun, sealant
Fly cutter
Gage, air pressure, 100 psi
Gage, vacuum, 32 in. Hg
Gloves, heat insulating
Gloves, white cotton fiber
Gloves, rubber or neoprene, surgeons'
Heat lamps, 200 to 350 watt (explosionproof)
Hole saw assembly
Hose, vacuum w/fittings
Knife, putty
Knife, pocket
Micrometer, depth
Micrometer, gap type
Micro stop, drill
Pen, ink marking
Power supply, 115 volt, 60 cycle, ac
Pressure plate, 0.125- and 0.250-inch aluminum
Probes, vacuum, connector
Pyrometer, 0° to 400° F, automatic recording
Router bits, assorted sizes
Router motor, pneumatic or electric (explosionproof for fuel areas)
Router templates
Safety glasses or shield
Saw, reciprocating, pneumatic or electric (explosionproof for fuel areas)
Scribe
Spatula, wood or metal
Tin snips, metal cutting
Vacuum cleaner, industrial or hand-type
Vacuum source
Wire, thermocouple, type J or equivalent

6.9.1 DAMAGE TO ONE OR MORE LAYERS OF LAMINATES

This type repair can be used for midpanel repair and when corrosion between layers of the laminate is a problem.

1. Locate the center of the damage area. Using a marking pen, mark coordinate lines at the edge of the damage which, if extended, would pass through the damage area center.

2. Mask off around the damage area to prevent further surface damage. Use aluminum foil or polyester tape for aluminum surfaces or lead foil or polyester tape for titanium surfaces.

3. Lay out a router-cutting pattèrn that extends a minimum of 0.25 inch beyond the damaged area (see fig. 6-70). If a standard stock router template is nonexistent, make a template per instructions in section 8.1.1.

4. Tape the router template in place over the damage area using double-backed tape. Align with panel edge and coordinate lines for position.

5. Select a router assembly and router bit. Adjust the bit to the proper cutting depth. Make the router cut.

   NOTE: If the damage extends to all the laminate layers the first routed cut may be a through-cut as shown in figures 6-68 and 6-69.

6. Reset the router depth for the second cut if required as shown in figure 6-70. This requires that the first router templates be removed and replaced with a new template that includes allowance for the overlap dimensions. Position the router assembly and make the second router cut.

7. Remove the pieces of damaged skin. If the skin does not lift up by finger pressure, pry loose with a sharp chisel or knife. Dry ice may be used to embrittle the adhesive for easier removal (see sec. 7.3.2).

8. Remove any organic finish remaining around the cut-out where the patch plate will be bonded using abrasive paper (180- or 220-grit). Finish the surface with 400-grit abrasive paper or nylon abrasive pads. Substitute emery cloth for abrasive paper on titanium assemblies.

9. Remove all sanding dust and debris with a vacuum cleaner.

10. Fabricate the sheet metal details:

    a. Select the material to be the same as that being repaired. The thicknesses shall be the same as that of the original material. If a single plug is to be used to replace more than one skin layer allow for the eliminated bondline thickness.

    b. Lay out the skin plug(s) and patch plate(s). Add the required overlap dimensions. Allow for a minimum overlap of 1.0 inch or as specified by the responsible engineering authority. If the patch plate is at the edge of a panel, add two overlap dimensions in length and only one to the width. If the patch plate is for a midpanel repair, add the overlap dimension to all sides or the periphery of the plates.

    c. Cut the skin plug(s) and patch plate(s) to size.

    CAUTION: Cutting of Titanium Details Requires Special Tools. Consult the Proper Document For Proper Tools, Speeds, Feeds, Etc.

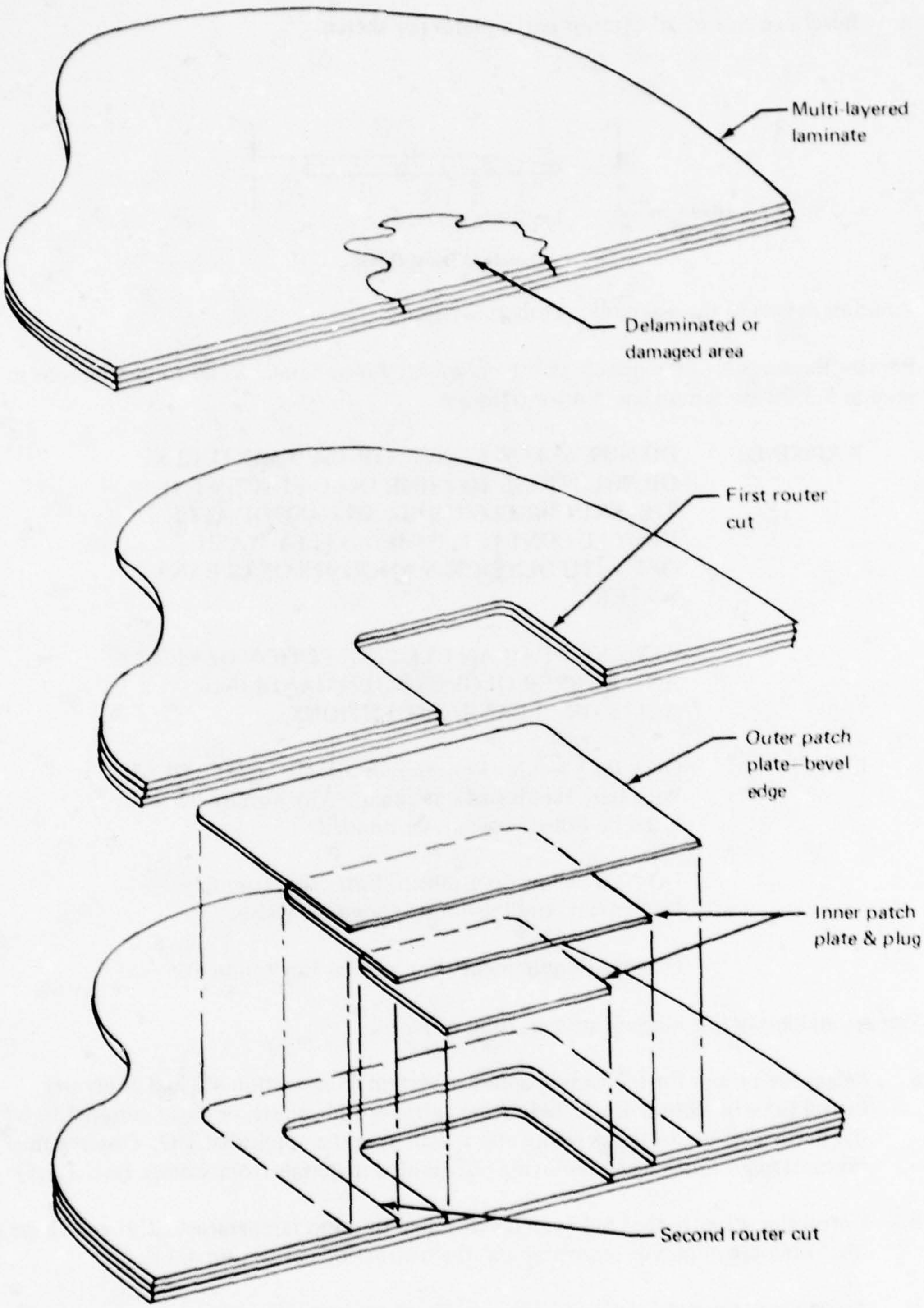
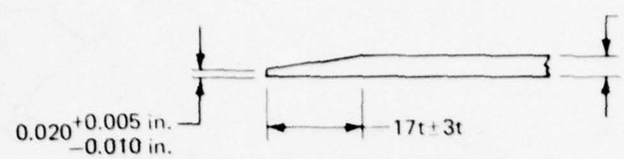


Figure 6-70.—Repair of a Delaminated Skin Area

d. Bevel one side of all exterior patch plates per sketch.



Sketch of Bevel Detail

11. Prefit all details to the assembly. Trim as necessary.

12. Prepare the surface of the details and the assembly for bonding. Refer to instructions in section 5.3 for aluminum and 5.4 for titanium.

WARNING: **DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH THE SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH GENEROUS AMOUNTS OF CLEAN WATER.**

ALWAYS WEAR AN EYE PROTECTION DEVICE AND RUBBER GLOVES WHEN HANDLING ACIDS OR CLEANING SOLUTIONS.

CAUTION: **Once the Cleaning Procedure Starts, DO NOT TOUCH With Bare Hands or Contaminate Any Surface That Is To Be Filled, Coated, Or Bonded.**

DO NOT Allow Solutions to Enter the Assembly Or Contact Any Previously Cured Adhesive.

Observe Requirements For a Clean Environment.

13. Prepare and apply the adhesive primer, film, or paste:

a. Select the primer for the chosen adhesive system from section 4.2 and apply per instructions in section 4.3.1. Select the adhesive film, sheet, or paste required to withstand the particular service temperature and specified in the applicable T.O. Observe the precautionary notes when removing refrigerated materials from storage (sec. 1.2.5).

b. Unroll the adhesive that has been conditioned to room temperature. Cut and shape the film using the details as templates and the instructions in section 4.3.2.

c. Assemble the metal details and adhesive layers for bonding.

14. Locate a minimum of three thermocouples around the patch plate(s). Hold in place with nylon or polyester masking tape.

15. Remove the tape used for protective masking.

16. Apply bagging materials per instructions in section 7.11.

17. Cure as instructed for the particular material systems in section 4.2.

18. Debag the assembly after the cure cycle.

WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT TOOLS OR EQUIPMENT.

19. Inspect the bonded repair per instructions in section 10.0.

20. Clean the adhesive flash areas per section 7.12. Wipe with clean, dry cheesecloth.

21. Prepare and apply aerodynamic sealant per section 4.3.6 or the applicable aircraft T.O.

22. Apply a replacement finish per section 4.3.7 or the applicable aircraft T.O.

7.0 LARGE AREA REPAIRS

7.1 INTRODUCTION

The procedures presented in this section are intended to serve as a guide for making sizable permanent repairs to bonded structure. A description of standard operations is provided that will have application regardless of the particular aircraft model.

There may be limitations as to the size or type of repair that can be made by a particular maintenance facility. These, to a large extent, are determined by the availability of equipment such as surface preparation tanks, autoclaves, or bonding tools. These limitations primarily apply to operational bases and are specifically defined by the responsible ALC or other maintenance authority.

In general, if large area repairs are to be satisfactorily accomplished, cleaning tanks, corrosion resistant primer application equipment, controlled atmosphere assembly areas, autoclaves for pressure curing, and trained and certified personnel are considered absolutely essential.

Emphasis should be placed on making the repair in a good workmanship manner. Repair part details should be preassembled prior to bonding to ensure proper fit. The bonding tools must be carefully designed to hold the part in proper contour and prevent slippage or crushing of the details during cure. Special care must be taken in preparing the metal surface for bonding. The quality of the bond surface to a large extent determines the adhesive bond strength and resistance of the bond to environmental exposure.

During the repair activity, give special attention to the following items:

WARNING: **OBSERVE ALL LOCAL SAFETY PRECAUTIONS AND THOSE DESIGNATED IN SECTION 1.3**

DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH GENEROUS AMOUNTS OF CLEAN WATER.

ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND CLEANING SOLUTIONS.

7.2 DAMAGE EVALUATION

A careful assessment of the extent of damage is an important part of the repair procedure. First, it allows a definition of the damage boundary. It is not an uncommon occurrence to make a repair and then find that the damage has extended beyond the repaired area. Secondly, the damage evaluation allows an accurate estimate of the repair cost to be used as a basis for the repair-or-replace decision.

Procedures for damage assessment are covered in section 2.0. Nondestructive inspection methods are covered in section 10.0.

7.3 DAMAGE REMOVAL METHODS

This section describes methods that have been effectively used to remove the damaged bonded material. If the material is removed properly, the subsequent repair can be made more easily. Care should be taken so as not to extend the damage. Proper tools must be used to cleanly cut the core. Some adhesives, especially those used for high temperature applications, may peel quite easily. This is an asset to removing damaged skin or doubler material. Special care must be taken, however, to prevent the peeling from causing delamination beyond the repair boundary.

It is recommended that paint strippers not be used unless all adjacent areas that might become contaminated are carefully masked, e.g., adhesive bondlines, open core areas, etc.

Normally adhesives should be left on surfaces that will be rebonded if the original adhesive appears to be in good condition and is firmly bonded. This will provide an excellent surface for the repair bond.

7.3.1 REMOVAL OF SKIN AND DOUBLER MATERIAL

Numerous types of mechanical equipment are available to cut, slit, rout, or saw the aluminum or titanium material. Equipment commonly used includes the high speed router, jitter or saber saw, or the slotting saw. These are described in section 8.1.3.

The high-speed router shown in figure 7-1 is both convenient and versatile. The depth of cut can be easily adjusted. It can be used against a template to define the cut outline.

Typical router cuts to remove damaged material are shown in figure 7-2. The cuts in the figure were made to repair damage to the edge of an F-5 landing gear door. A flush replacement skin section is to be installed on the flat exterior surface, thus a wider cut is made on the interior surface to allow for installation of an interior patch plate.

The router template is made of either 1/8-inch-thick aluminum or plastic. It is attached to the part surface with double-backed tape. In making the template, appropriate allowances must be made for the diameter of the cutter and the thickness of the guide bushing as shown in figure 7-3. The width of the step cut for this particular case is the width of the template plus the cutter diameter plus twice the set-back distance for the guide bushing.

After routing, the template and double-backed tape are removed. A beveled edge putty knife may be used to lift the edge of the skin. It may then be gripped with a pliers or vise grips to peel (see fig. 7-4).

WARNING: **PULL SLOWLY. BE AWARE OF THE SUDDEN RELEASE AT THE END OF THE PULL.**

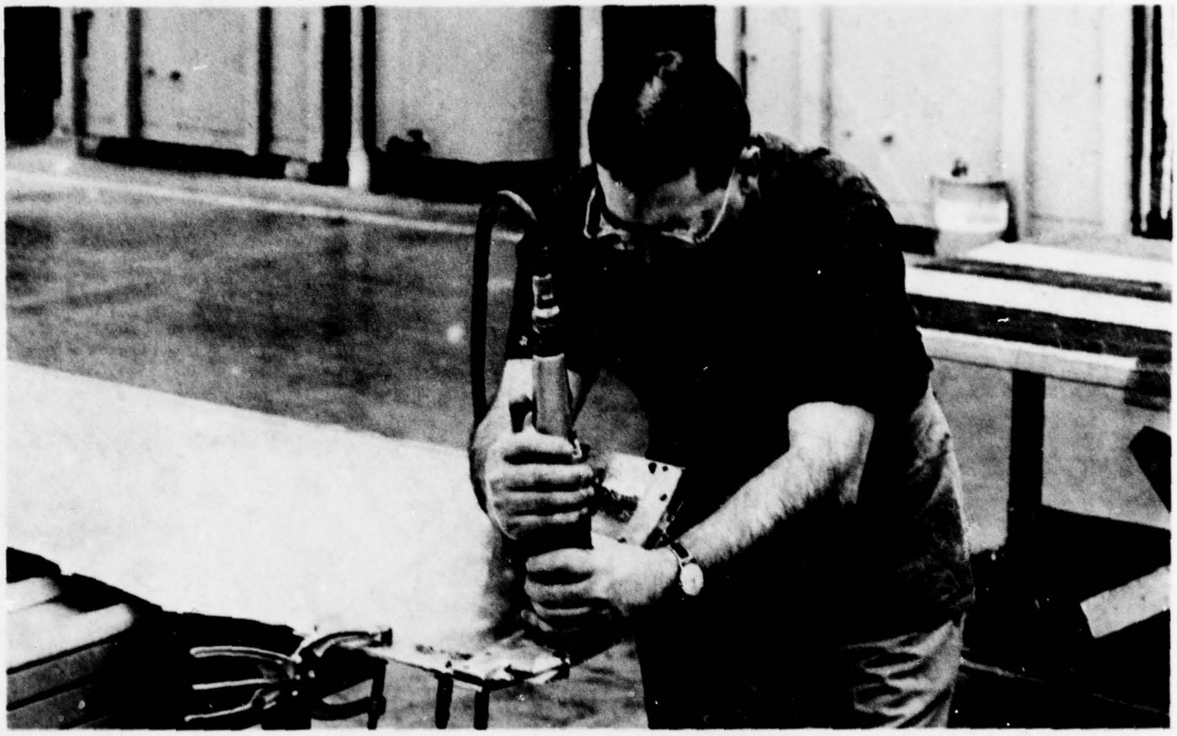


Figure 7-1.—Using High Speed Router to Remove Damaged Material

Where it is necessary to remove a large section of skin, again a beveled edge putty knife or chisel may be used to start the face separation. This is illustrated in figure 7-5a. The skin is shown being peeled from the surface in figure 7-5b. If the adhesive has high peel strength, it may be helpful to slit the skin in strips with a slotting saw as shown in figure 7-6. It may then be possible to grip and peel the strips with a pliers, or the slotted sardine-can-opener-type tool may be used.

7.3.2 USE OF DRY ICE

When dry ice (solid carbon dioxide) is applied to the bonded skin surface, it tends to embrittle the adhesive and lower its peel strength. An effective procedure is to cover the skin with chunks of the dry ice and then cover this with an insulating blanket for a few minutes. Usually an otherwise tough adhesive can then be peeled quite easily.

WARNING: **DRY ICE SHOULD BE HANDLED WITH INSULATED GLOVES AND WHILE WEARING SAFETY GOGGLES. FROSTBITE MAY RESULT IF DRY ICE COMES IN CONTACT WITH THE SKIN OR EYES. IN CASE OF CONTACT, OBTAIN MEDICAL ASSISTANCE IMMEDIATELY. PROVIDE VENTILATION FOR CARBON DIOXIDE PER LOCAL SAFETY REGULATIONS.**

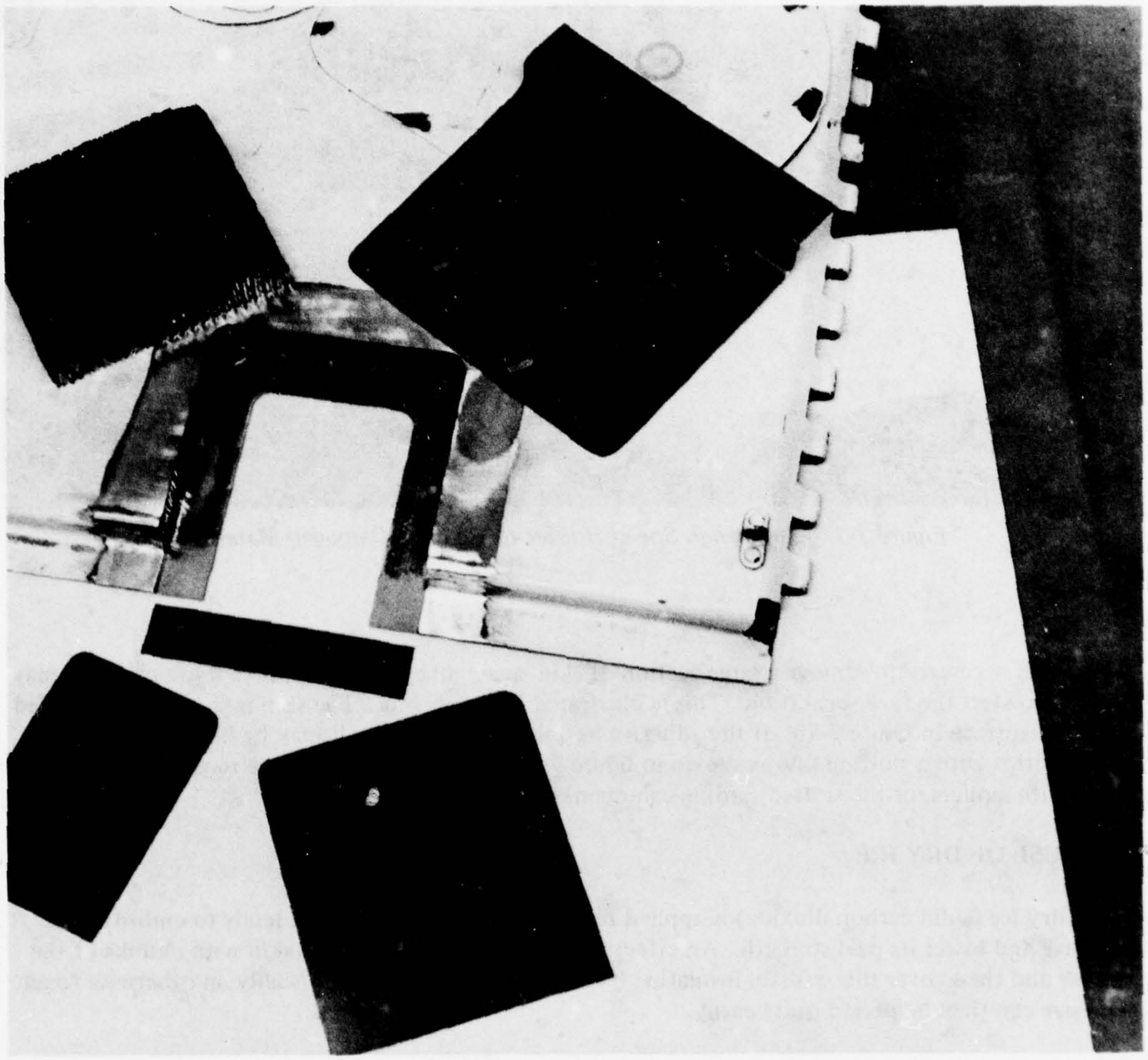


Figure 7-2.—Router Cuts to Remove Edge Damage on Landing-Gear Door-Repair Details Also Shown

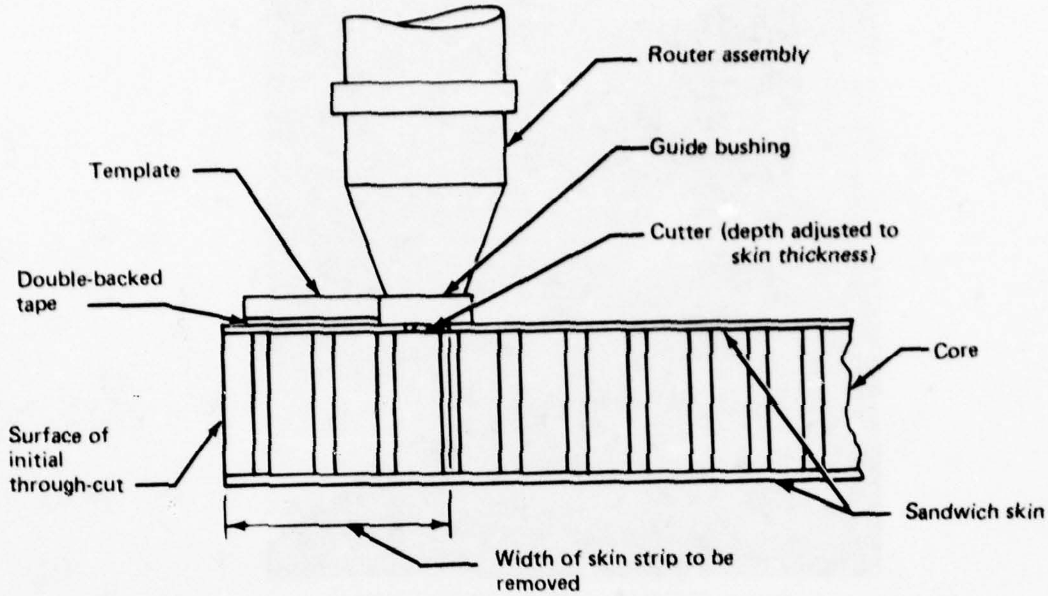


Figure 7-3.—Use of High Speed Router to Remove Strip of Sandwich Skin

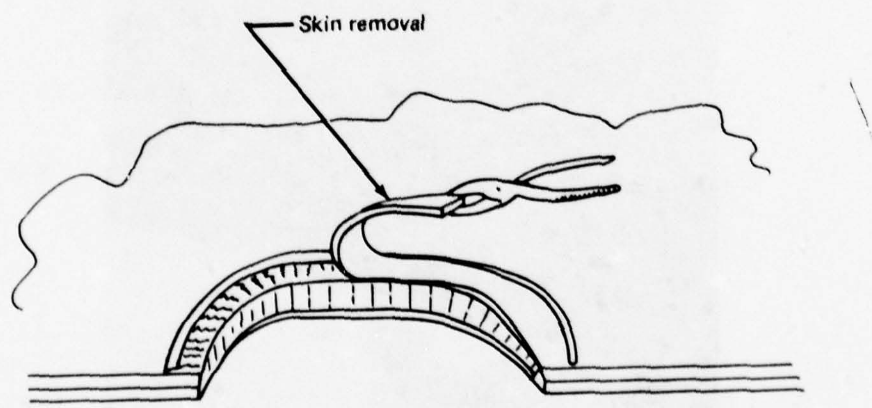
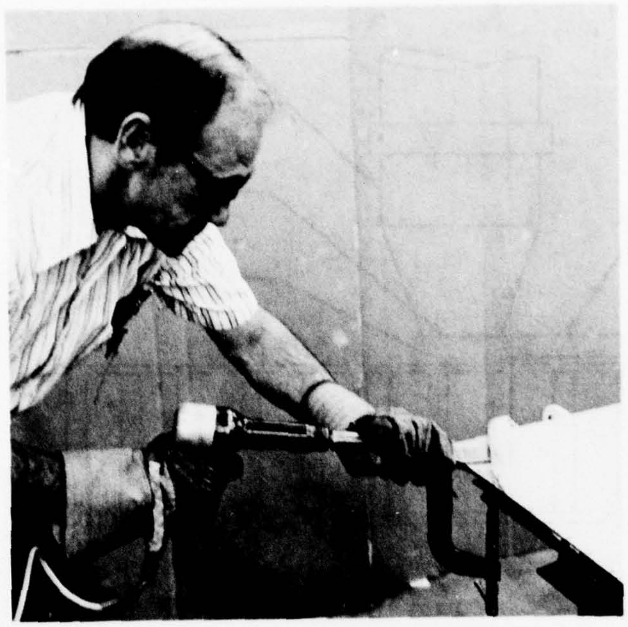
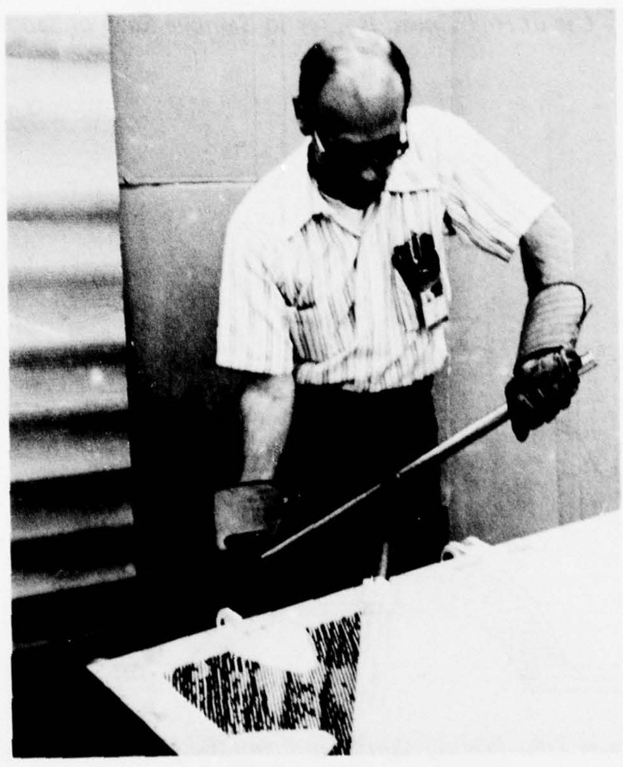


Figure 7-4.—Peeling Skin Strip From the Honeycomb Core



a. Starting Skin Removal With Air-Powered Chisel



b. Peeling Sandwich Skin With "Can Opener" Type Tool

Figure 7-5.–Removal of Large Skin Sections

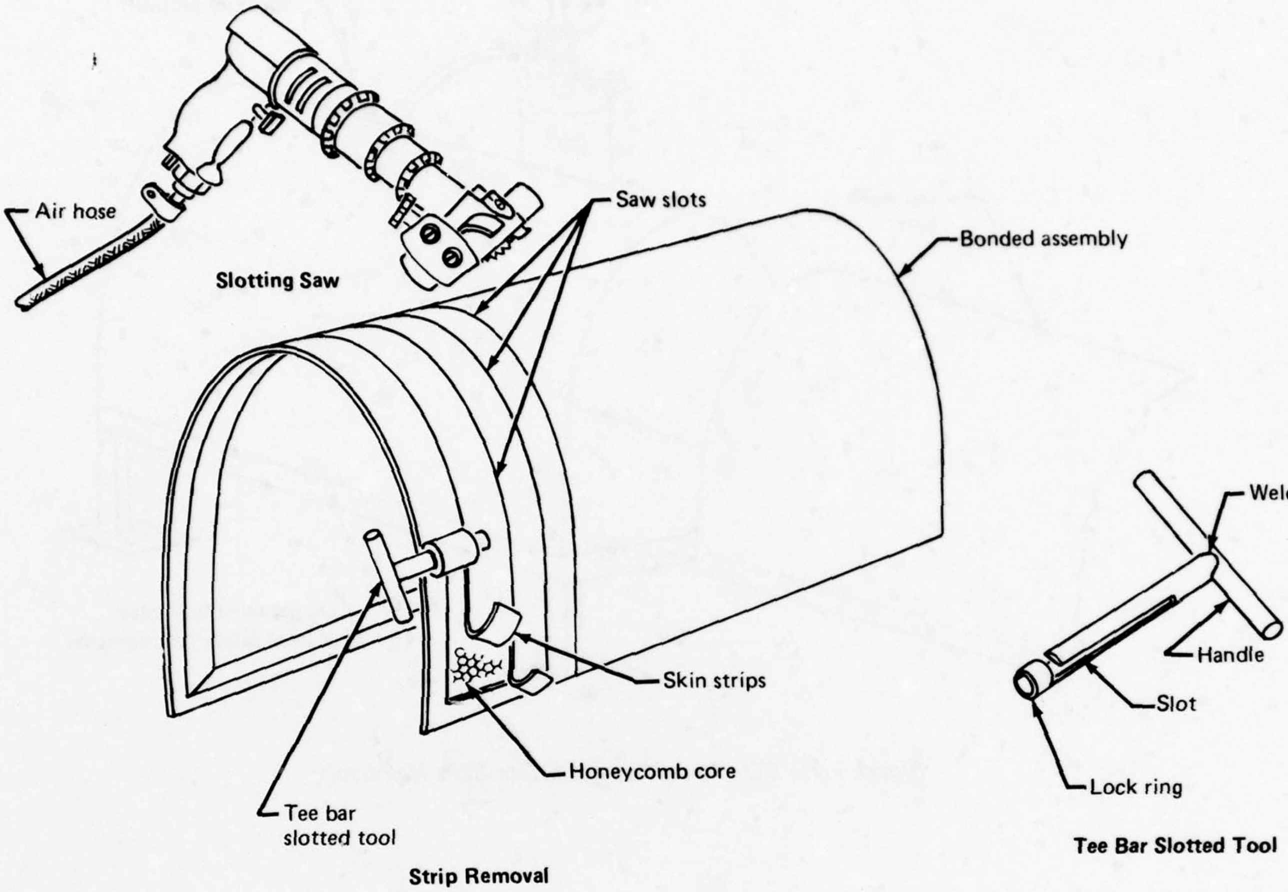


Figure 7-6.—Honeycomb Panel Skin Cut in Strips to Facilitate Removal

In some cases it may be advantageous to construct a special insulated enclosure to surround the entire assembly. A typical retort is shown in figure 7-7. The damaged assembly is loaded into the retort which is then flooded with bottled carbon dioxide gas. The emitted gas is chilled to a dry ice condition by its expansion to atmospheric pressure.

After approximately 30 minutes the assembly is removed and the skin peeled. Care should be taken in handling the cold assembly to prevent frostbite (see the previous warning note). Other methods that may be considered are the use of liquid nitrogen or, in some cases, the application of heat.

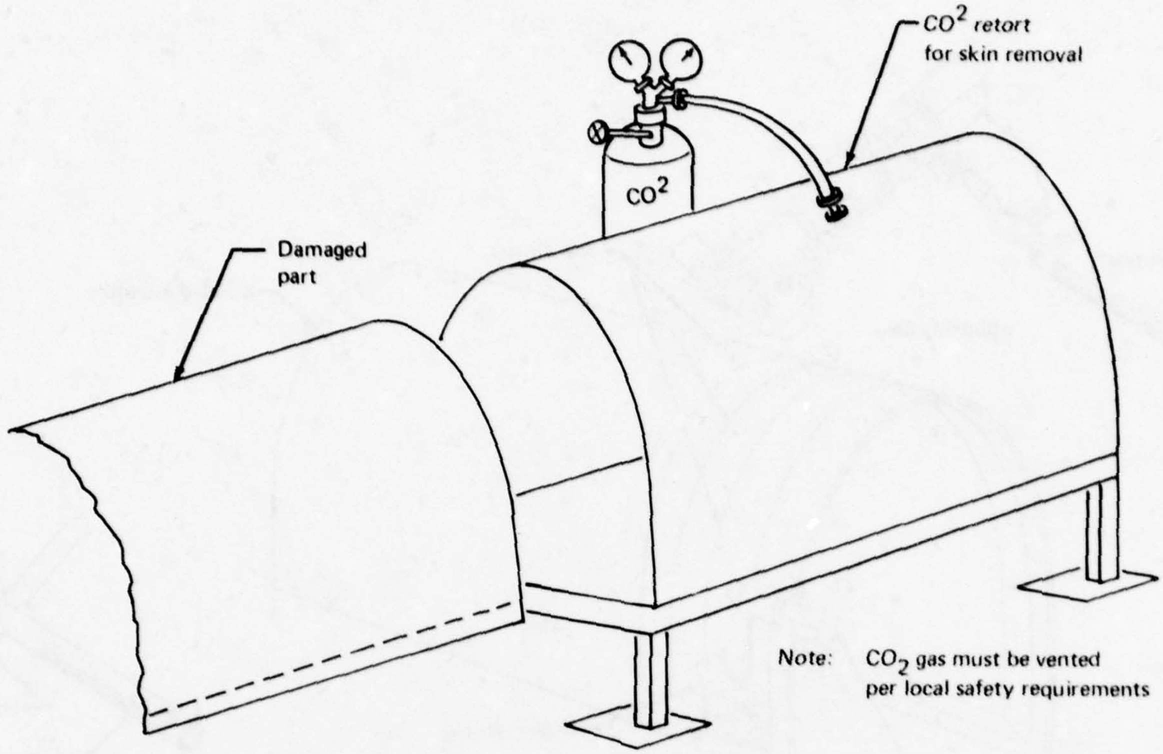


Figure 7-7.—CO_2 Retort to Facilitate Skin Removal

7.3.3 REMOVAL OF CORE MATERIAL

Removal of light density core may be accomplished using a sharp pocket knife or putty knife. The procedure is illustrated in figure 7-8.

For the condition shown in the figure, vertical cuts are made through the core proceeding along the edge of the routed skin. The knife is then slid along the inner skin surface to make the horizontal cut. The core is removed down to the adhesive bondline.

In the case of denser core it will be necessary to use machining techniques. A core removal operation is shown in figure 7-9. An abrasive disk is being used with a portable high-speed air motor. A valve stem cutter may also be effectively used for this operation.

Following removal of the core, the adhesive surface may be smoothed using a portable high speed motor and a sanding disk (see fig. 7-10). Care should be taken not to penetrate the adhesive layer to expose the base metal. After this smoothing procedure use a vacuum cleaner to clean up the sanding dust and debris. Dry wipe with clean cheesecloth.

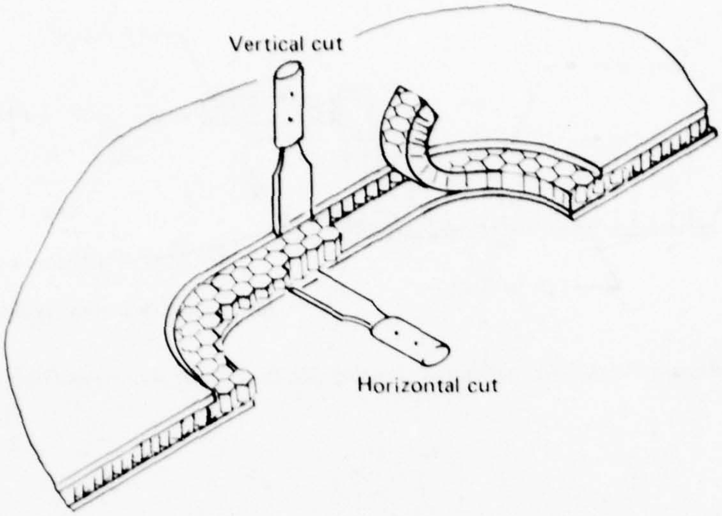


Figure 7-8.—Removal of Core With Sharpened Putty Knife

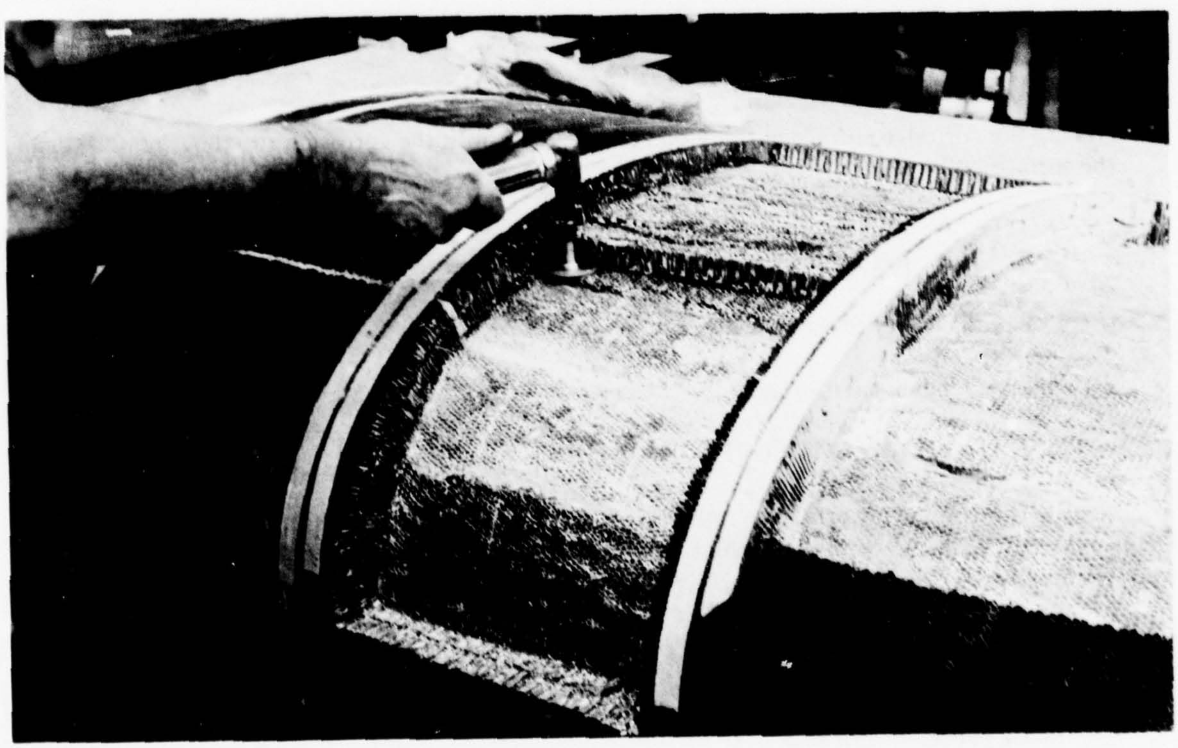


Figure 7-9.—Damaged Core Being Removed With Abrasive Disk Mounted in High Speed Air Motor

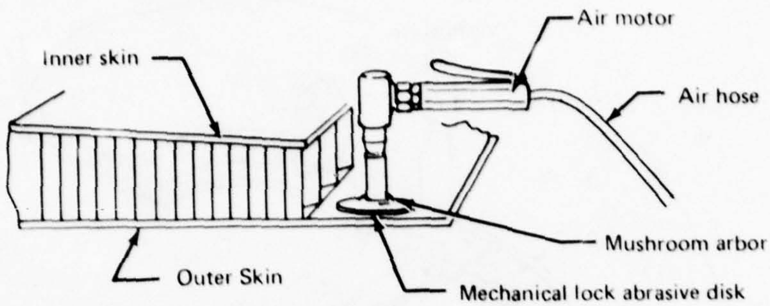


Figure 7-10.—Smoothing Adhesive Surface With Abrasive Disk

7.3.4 REMOVAL OF SURFACE CORROSION

The existence of corrosion on any part or surface is considered the same as physical damage and must be removed or the part replaced. In general, light corrosion on skins, doublers, or stiffeners can be removed and the surface refinished. When the corrosion has advanced to the stage of pitting and scale, the parts should be replaced. When honeycomb core is affected by corrosion, it loses its luster and appears white or grey in color. In more advanced stages, it becomes brittle and tends to flake away. Core corroded to any extent should be replaced. Skins having light corrosion may be treated as follows:

1. Abrade the corroded surface with nylon abrasive pads until the corrosion residue is removed and the surface polished.

   NOTE: An aluminum oxide abrasive wheel may be used prior to the abrasive pads.

2. Use a vacuum cleaner to remove all corrosion dust and debris.

3. Wipe the abraded area with clean, dry cheesecloth.

7.3.5 REMOVAL OF ORGANIC SURFACE FINISHES

In general, it is recommended that the finishes be removed mechanically with evaporative solvents. Strippers are difficult to contain and can cause serious damage if they penetrate into crevices or adhesive bondlines.

1. Removal of polyurethane coatings:

   a. Sand the surface with nylon abrasive mat (MIL-A-9962) or 180- to 200-grit aluminum oxide paper. Finish with 380- to 400-grit paper.

b. Wipe dry with clean cheesecloth.

2. Removal of other organic coatings:

a. Moisten clean cheesecloth with solvent and wipe surface until finish is dissolved.

b. Dry wipe with clean cheesecloth.

7.3.6 REMOVAL OF MOISTURE

IN GENERAL, IT IS RECOMMENDED THAT WHERE MOISTURE IS DETECTED IN A SANDWICH COMPONENT, THE AREA BE OPENED, INSPECTED FOR CORROSION, AND REPAIRED. In some cases, however, if no internal damage is indicated, i.e., if it is known that the moisture has just entered the panel, it may be elected to simply find the entrance point, remove the moisture and reseal. The following procedures are included to accomplish water removal.

Procedure No. 1

1. In each area where water is found, drill a 1/8-inch-dia hole in the bottom surface at the lowest point. Drill a 1/8-inch-dia hole in the upper surface at the opposite extreme edge of the water accumulation area.

2. Install a heat blanket* of suitable size and vacuum bag at the lower extreme end of the water accumulation area; heat to $170^{o} \pm 10^{o}$ F for 2 or 3 hours.

3. Cover the opposite 1/8-inch-dia hole with masking tape.

4. Apply vacuum of up to 15 or 20 inches of mercury.

5. Allow pump to operate for approximately 3 to 5 minutes with the top hole closed. Remove tape from the top hole and allow air to enter for approximately 3 minutes. Replace the tape to close off the upper hole.

CAUTION: **Damage to the Core Will Occur If the Upper Hole Is Left Open For More Than 5 Minutes With a Vacuum Applied.**

6. Repeat steps 3, 4, and 5 for approximately 2 hours.

7. Stop heat and vacuum. Remove heating method and vacuum bag.

*As options, the part may be placed in an automatically controlled autoclave or an air-circulating oven.

8. Reinspect. If water is completely removed, proceed to next step. If water remains in the area but is less than when previous 5 steps were last started, repeat those steps. If no change after third try, proceed with "Procedure No. 2."

9. Seal holes that were drilled in previous steps. Seal with sealant from section 4.3.6 which lists mixing and handling instructions.

Procedure No. 2

If water cannot be removed by the first procedure then resort to the following as illustrated in figure 7-11.

1. Cut a hole approximately in the center of the affected area, using the following hole-size to water-diameter as a guide:

Water accumulation dia (inches)	Hole size required (inches)
2.0	0.75
3.0	1.00
4.0	1.50
5.0	1.75
6.0	2.00

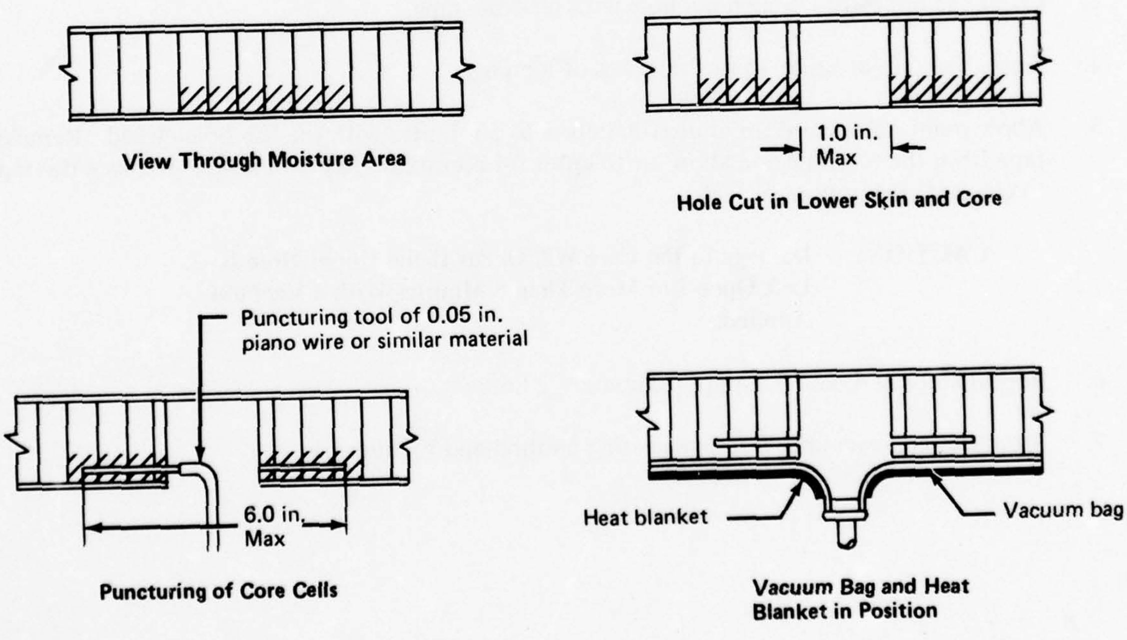


Figure 7-11.–Procedure for Removal of Moisture From Honeycomb Sandwich Assemblies

2. Manufacture a puncturing tool of 50 mil piano wire, or similar material (see fig. 7-11).

3. Locally puncture the honeycomb core cell walls containing water. Puncture at the lowest point possible without affecting the bond line.

4. Install the heat blanket and vacuum bag over the affected area (see sec. 7.11). The part can also be heated in an air-circulating oven or an automatically controlled autoclave.

5. Apply a vacuum of 15 to 20 inches of mercury and heat to $170^{\circ} \pm 10^{\circ}$ F until all the water is removed. This may take from 2 to 4 hours.

6. Stop heat and vacuum. Remove heat source and vacuum bag.

7. Reinspect to make sure all the water has been removed. If water is not all removed, repeat previous 4 steps until water is removed.

8. Repair the hole or core area as necessary per instructions included in the procedure section 6.0.

9. Reseal the edges if the panel is damaged per instructions in section 4.3.6 or the applicable aircraft T.O.

7.4 REPAIR MATERIAL SELECTION

Refer to section 4.0.

7.5 IN-PROCESS QUALITY ASSURANCE

It must be emphasized that postrepair inspection methods are not sufficient to ensure that a quality repair has been accomplished. These methods may be used to detect gross defects. Such properties as a high level of bond strength or environmental durability, however, can only be confidently obtained through careful step-by-step processing and the use of adequate in-process controls. The following is a guide to in-process quality control steps that should be taken. These steps are particularly applicable to the processing of aluminum.

7.5.1 GENERAL

- Control test assemblies for aluminum should be associated with processing steps rather than individual parts.
- Control should be based on the following processing steps:
  a. Tank clean-line process
  b. Primer process
  c. Cure process

Tank Clean-Line Process Control:

1. Process one wedge or peel test assembly with each cleaning load. Use 2024-T3 clad or nonclad details. For a description of the wedge test procedure, see section 4.4.1. The wedge test is preferred for 250° F curing epoxy adhesives. The peel test may be used for 350° F curing systems. The peel test is described in MIL-A-25463.

2. Prepare and identify a process control data sheet to accompany the test panel through the test evaluation. Include the following information in this form:

   - Clean-line load date and time
   - Primer and adhesive lot and container or roll validation date
   - Primer and adhesive application date and time application is completed
   - Primer drying identification
   - Cure identification
   - Test results and disposition of load

3. Locate the test assembly details in a central location in the cleaning load with the production details distributed uniformly.

4. The process control test details should accompany the production parts through all stages of the surface preparation.

7.5.2 BAKE OR CURE CYCLE PROCESS CONTROL

1. Identify the temperature and pressure charts with the assemblies, subassemblies, and process control test details processed in each particular bake or cure cycle.

2. Verify the acceptability of the bake or cure cycle.

7.5.3 EVALUATION OF PROCESS CONTROL RESULTS

1. Clean line acceptance and rejection criteria: If any one of the wedge specimens, using a standard 250° F curing adhesive, shows crack growth greater than 0.75 inch, or if the average of 5 specimens exceeds 0.25 inch, after 1 hour exposure to 120° F/100% relative humidity conditions, recycle the corresponding parts and take corrective action. The peel specimens should show 100% cohesive failure to be acceptable.

   Reject the parts and take corrective action if any of the new specimens fail above the limits.

2. Record the results and disposition on the process control form.

Procedures and quality inspection results should comply with requirements for adhesive bonded structure as specified in MIL-A-83376 and MIL-A-83377.

7.6 FABRICATION OF DETAILS

7.6.1 SHEET METAL

With the exception of the honeycomb core, the metal parts will be formed using conventional metal working techniques. Special care is required in forming to obtain acceptable "closer than standard" tolerances. Allowance must be made for the thickness of bondlines when applicable.

Where the metal details are cleaned and primed but not immediately bonded in an assembly, they shall be wrapped and stored as noted in section 1.2.5.

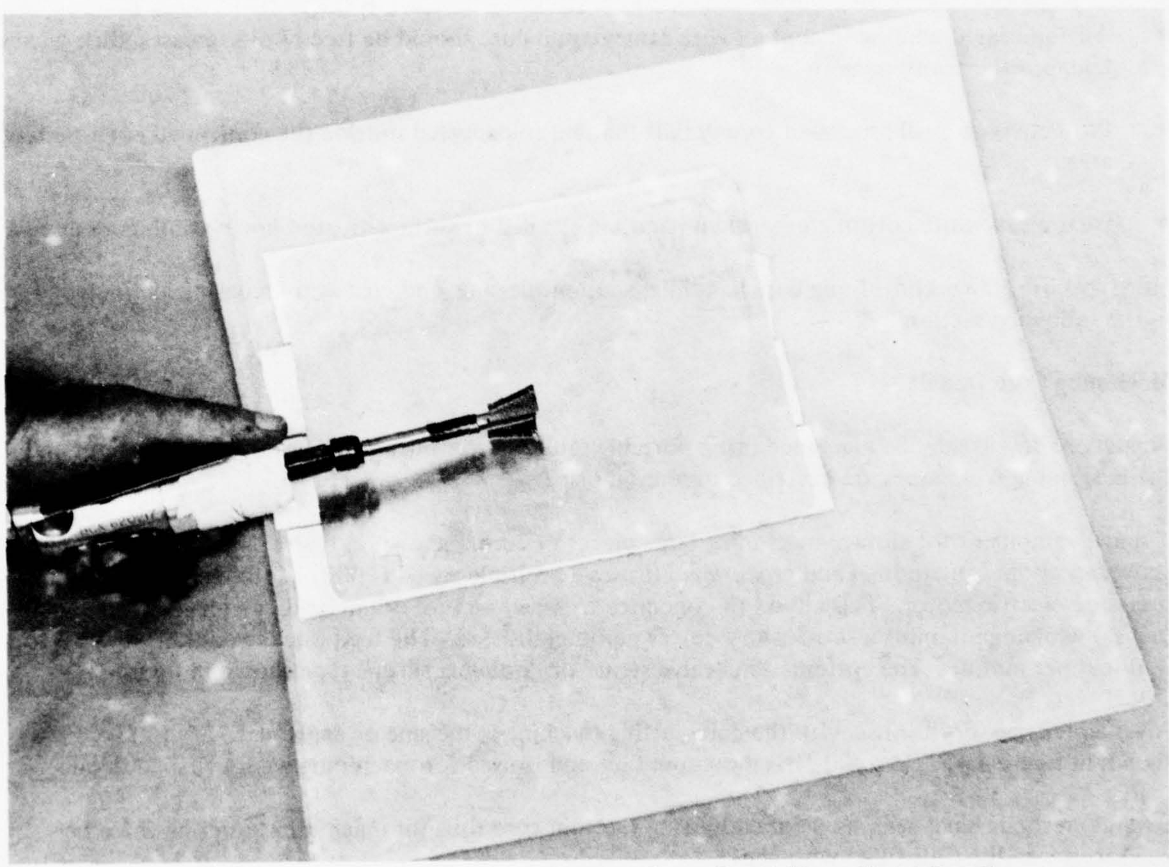


Figure 7-12.—Roto-Peen Being Used to Form Small Sheet Metal Detail

7.6.2 PROCESSING OF HONEYCOMB CORE

The fabrication of honeycomb core details is a process that must be done carefully because of the core's fragility. Preventing damage requires special consideration for handling, processing, and in using proper fabrication techniques. With reasonable care, core details can be formed to limited radii and machined to close tolerances. The availability of experienced personnel and properly maintained equipment is important. The following general procedures concerning core handling and storage should be regarded:

- Handle core only when necessary
- Do not twist or distort the core when removing it from the shipping container. If possible, store in the "as received" shipping containers.
- The storage and in-process hold area shouldbe free of contaminating agents.
- Before use, core details should be inspected for corrosion, etching, or contamination.
- All equipment coming in contact with honeycomb core should be free of oils, greases, dirt, waxes, talc, or other contaminants.
- Protective-wrap all processed core details that are transported outside the controlled environment area.
- Wear clean white cotton gloves when handling cleaned or surface-treated honeycomb core details.

More specific guides concerning core handling, shop processing, and custom purchasing are included in the following sections.

Machining Core Details

Small core details may be machined using portable tabletop routing equipment. This equipment and the machining techniques are described in section 6.1.2.

Typical equipment for surface-machining large pieces of core is shown in figure 7-13. The machine shown has both longitudinal and cross rails. It uses a multiple speed (7000, 14 000, and 21 000 rpm) precision electric motor. This allows the operator to select a range of cutter diameters (1/2 to 3 inches) while maintaining a satisfactory cutter peripheral speed. The feed rate is maintained at 50 to 200 feet per minute. The cutter is the "valve stem" or "bologna slicer" type shown in figure 7-14.

A valuable accessory for use with the core-cutting machine is the sine or angle plate (0° to 20° angle) shown in figure 7-15. The plate has a vacuum face and is used for machining wedge-shaped details.

Several methods have been used for stabilizing the thin core foils for machining. Among these has been to freeze the cells filled with water.

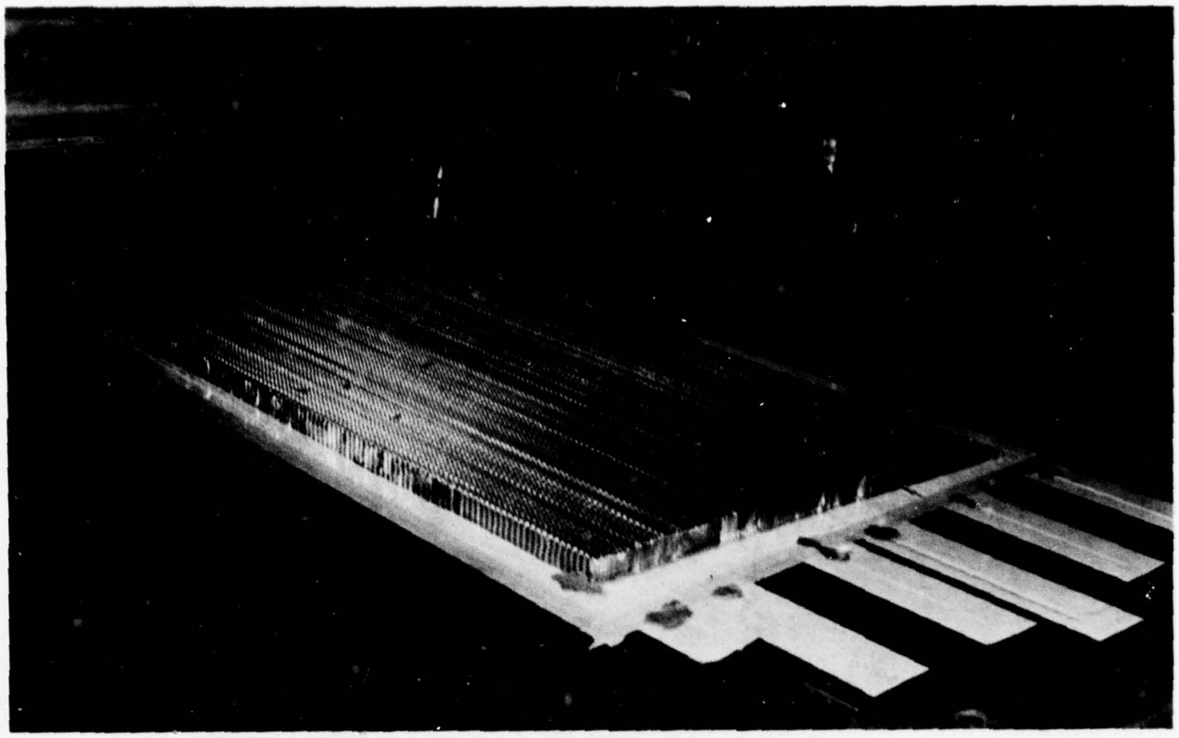


Figure 7-13.—Surface Machining Honeycomb Core

Using proper cutting techniques, the core can be satisfactorily machined without being filled. The main problem becomes one of holding the core in position. This may be accomplished by bonding nylon cloth to one honeycomb surface. The core can then be held to the machine base by vacuum. The method for bonding the cloth typically uses a flat aluminum plate as a base. This plate should be a minimum of 6 inches larger than the core piece to be bonded. The materials are stacked as shown in figure 7-16 for cure. The curing procedure is the same as that for normal bonding except the cure time and pressure (10 psi) is reduced.

After curing, the bagging material is removed and the core is ready for machining. After machining, the nylon cloth is peeled from the surface. This is made easier by placing the core in a degreasing tank, nylon side up, to soften the adhesive. Peel off the nylon cloth, then bake the core to remove the degreasing solution.

Another method of holding the core is by using a two-stage bonding operation. In the case of a typical trailing-edge tab, this is accomplished by making a first cure by bonding the rectangular core block to one skin, the front spar, and end ribs. This assembly is attached to the work bed for machining by vacuum chucking. The end ribs are used as a template to taper the core to proper contour (fig. 7-17).

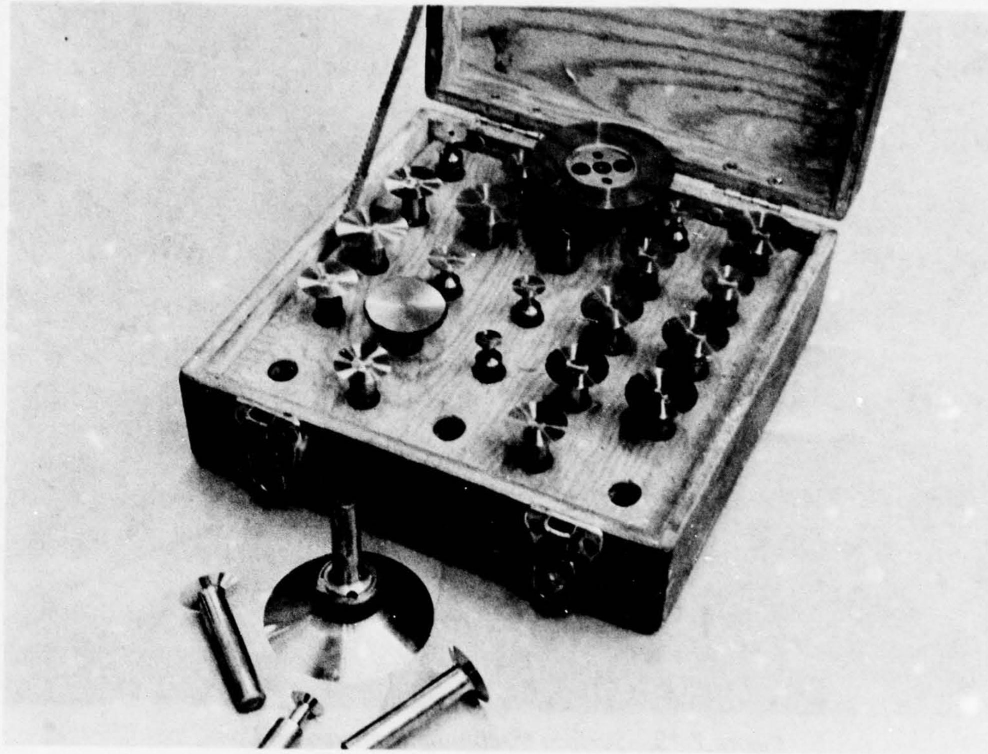


Figure 7-14.—Assorted Cutters for Machining Honeycomb Core

Honeycomb Core Forming

The best and most versatile equipment to form core details is generally of special design and only available at the core fabricator's facilities. Limited core-forming can, however, be done with selected sheet-metal-forming machines, provided proper procedures are used. Examples of usable machines are the Farnham pyramid roll (fig. 7-18) or the "pinch" type plate roll (fig. 7-19) having a sufficient gap (opening) to receive the core thickness. Accessories needed to accomplish this procedure include heat-treated aluminum sheets (caul plates); one heavy (0.063-inch) sheet for the lower surface and one thin (0.020-inch) sheet for the upper surface. Dapcoat 5020 is applied to the core side of each aluminum sheet to an 0.020-inch thickness. The following is a guide for core-forming limits:

Core density	Radius (inches)
Up to 3.1	20 times thickness
3.1 to 6.1	30 times thickness
6.1 to 8.1	40 times thickness

The roll forming process is accomplished by a number of fore and aft (back and forth) passes through the rolls. Depth is changed after each pass. This minimizes the roll pressure applied by the "top" or forming roll. The core density and core thickness determine the depth change for each pass.

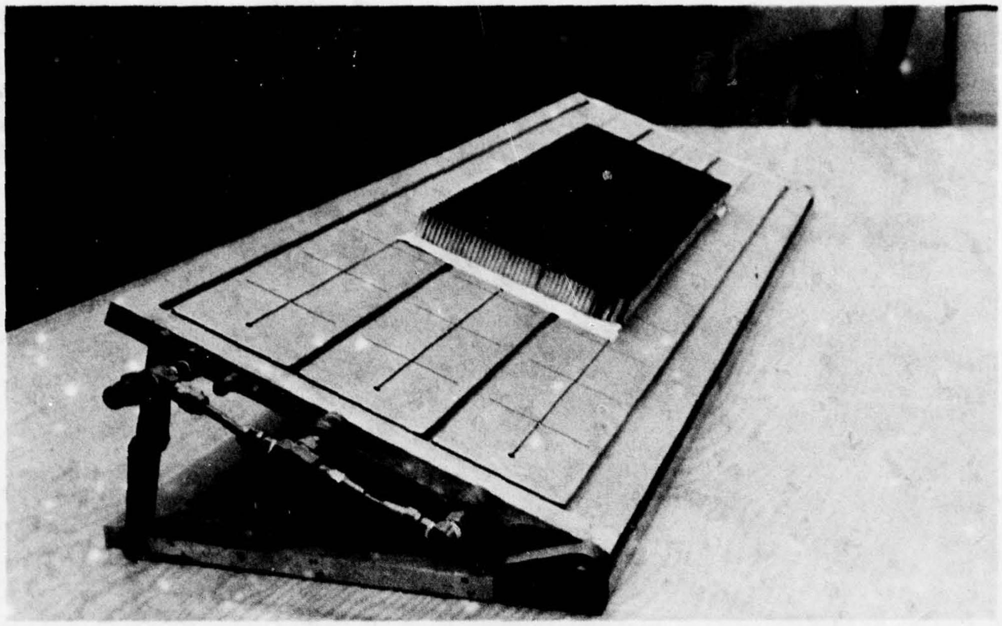


Figure 7-15.—Sine Plate for Making Angle Cuts on Honeycomb Core

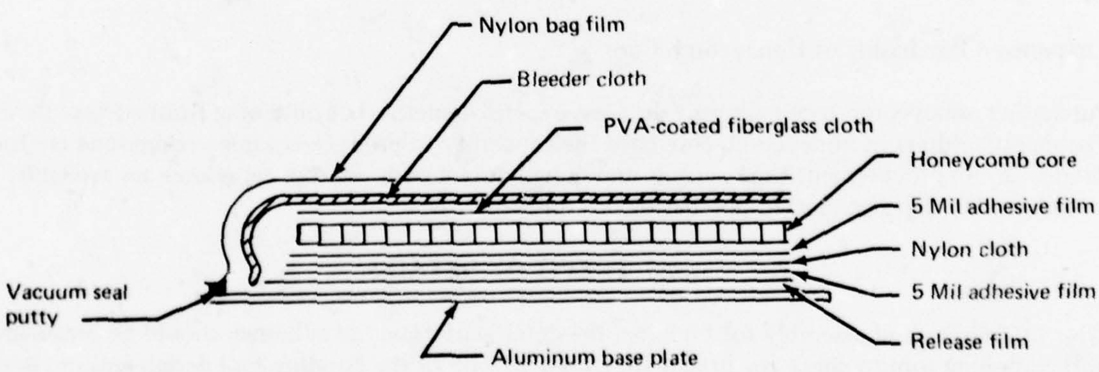


Figure 7-16.—Stack-Up of Materials to Bond Nylon Stabilizing Cloth on Surface of Honeycomb Core

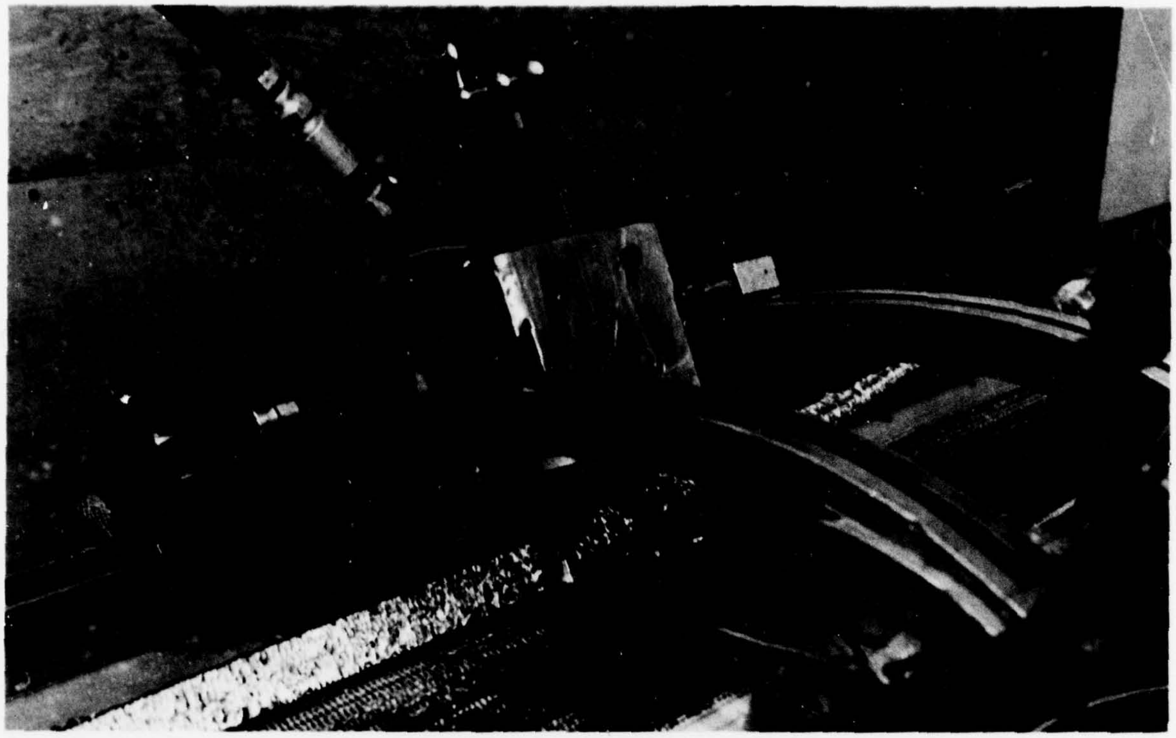


Figure 7-17.—Second Stage Machining of Core

When a core detail reaches the limit of a straight line element parallel to the roll, a phenomenon occurs that creates a synclastic reaction causing the detail to form an elliptical or dished shape. If the assembly being repaired has a shallow compound contour, this synclastic reaction may be advantageous.

Customized Purchasing of Honeycomb Core

Purchasing honeycomb core may provide a less expensive method of obtaining finished core details. The manufacturers of honeycomb core have the capability to produce complex compound contoured details. When procurement time permits and design drawings or contour templates are available, it is recommended that customized purchasing be considered.

7.7 PREFIT OF DETAILS

Prior to cleaning and assembly for bonding, the detail parts, less the adhesive, should be preassembled in the bonding tool to check for proper fit. (A description of the bonding tool design and use is given in sec. 9.0.)

Inspection of the detail parts prior to bonding is shown in figure 7-20. All surfaces should be checked for mating tolerances. Handmade details should be inspected and be free of cracks, dents, cans, burrs,

or dimples. Any uneven surface should not exceed 0.003 inch, including burrs. Details to be bonded should not be of steel stamped for identity.

Sheet metal details should mate to the adjoining surface using a light pressure (1 to 2 psi). Extruded or machined spar chords, fittings, and/or closures should match the part contour when 5 psi pressure is applied. The maximum gap should not exceed 0.005 inch.

Detail parts that do not fit properly must be reworked or refabricated prior to assembly.

Verification Film and Its Application

In some cases, especially when thick pieces are being bonded or where major size repairs are being made, it may be difficult to determine if the bonding surfaces are mating with proper fit. In these instances, the use of verification film (verifilm) is necessary. The technique involves making a pre-cure with the adhesive film sandwiched between two thin layers of release film. After cure the assembly is taken apart and the film examined for too-thin or too-thick areas. This allows discrepancies to be corrected before the cure. The verifilm can be retained as a permanent record of the mating surface fit.

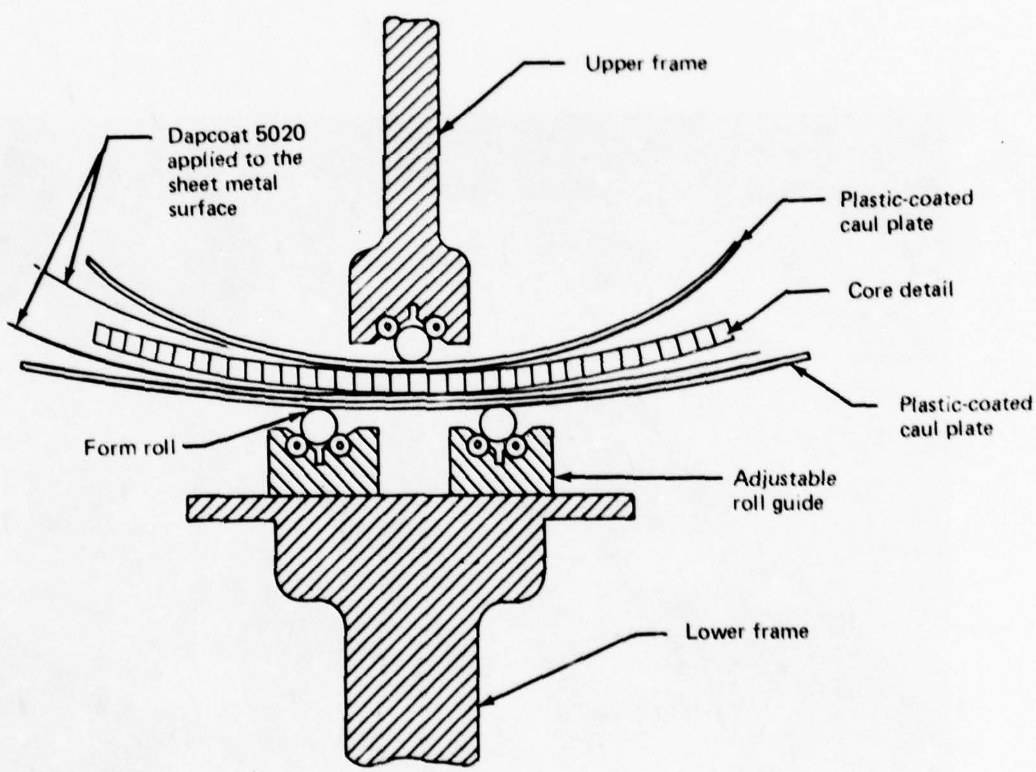


Figure 7-18.—Farnham Roll Being Used to Form Honeycomb Core

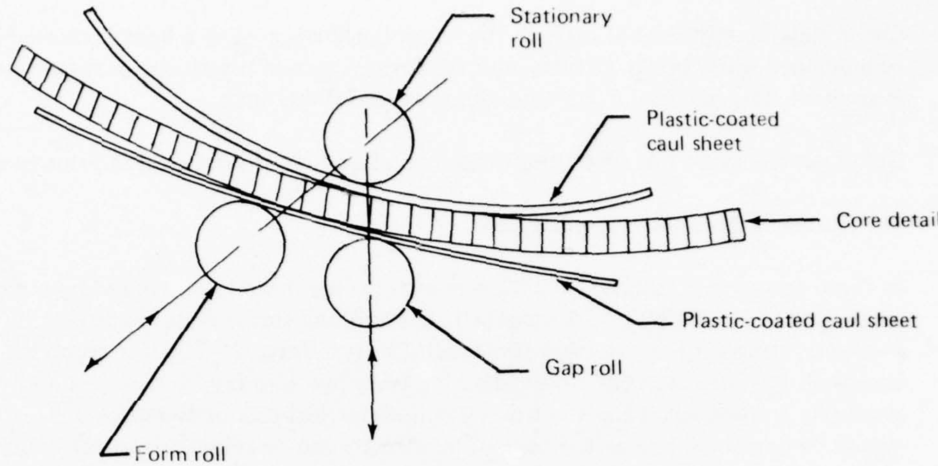


Figure 7-19.—Pyramid-Type Pinch Roll Used to Form Honeycomb Core

Figure 7-20.—Prefit Inspection Prior to Bonding

The verification film may be made up of one ply of 10 mil qualified shop adhesive sandwiched between two layers of 1- or 1-1/2-mil mylar, polyvinyl fluoride (PVF) film or modified halohydrocarbon polymer film. The release film should be wide enough not to inhibit the free flow of the adhesive. Proper layup of the verifilm laminate is important. All air is to be removed from between the adhesive and the release film.

The use of laminating rolls to produce the film is preferred. This allows the release film to meet the adhesive in a moving line contact and minimize air entrapment.

When laid up by hand, the release film is applied to the adhesive in a sweeping motion, starting at the center of one end and sweeping the hands out alternately to each edge (fig. 7-21).

7.8 SURFACE PREPARATION FOR BONDING

Preparation of the metal surface for bonding is one of the critical operations in obtaining a bond that is strong and durable. Surface preparation methods are described in section 5.0. Special care must be taken to prevent the cleaning solutions from contacting surrounding surfaces, especially the surface of high strength steel, or from entering crevices.

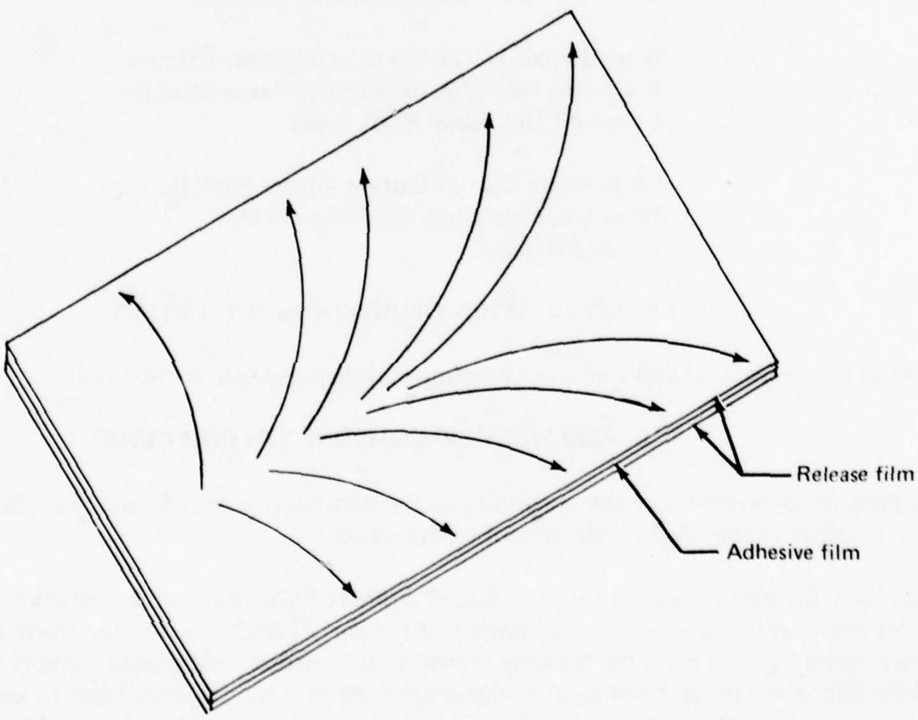


Figure 7-21.–Direction of Sweeping Air From Release Film

During the surface preparation procedure, give special attention to the following items:

WARNING: **OBSERVE ALL LOCAL SAFETY PRECAUTIONS AND THOSE DESIGNATED IN SECTION 1.3.**

DO NOT ALLOW CONCENTRATED MIXTURES OR SOLUTIONS TO COME IN CONTACT WITH SKIN OR CLOTHING. IN CASE OF ACCIDENTAL CONTACT, IMMEDIATELY WASH OFF WITH GENEROUS AMOUNTS OF CLEAN WATER.

ALWAYS WEAR EYE PROTECTION DEVICES AND RUBBER GLOVES WHEN HANDLING ACIDS AND SOLUTIONS.

CAUTION: **DO NOT Allow the Surface Preparation Solutions To Contact the Previously Cured Adhesive.**

Once the Cleaning Procedure Starts, DO NOT TOUCH With Bare Hands or Contaminate Any Surface To Be Filled, Coated, or Bonded.

If the Repair Is Not Continued Within 2 Hours Following Cleaning, the Cleaned Areas Shall Be Covered Using Clean Kraft Paper.

Clean White Cotton Lintless Gloves Shall Be Worn When Handling the Adhesive Or Cleaned Details.

7.9 APPLICATION OF BONDING MATERIALS

For instructions regarding application of bonding materials, refer to section 4.0.

7.10 ASSEMBLY OF COMPONENTS FOR CURE

The approaches described here for assembling of the part being repaired may be applied to either large area repairs or the small repairs described in section 6.0.

In assembling the part for cure, proper tooling or support fixtures are an important consideration. These are required to maintain proper contour of the part during cure, to keep the details from shifting position, and to react the bonding pressure. It is warned that proper support tooling is especially important in the bonding of wedge-shaped sections (i.e., trailing edges to keep the part from collapsing from the horizontal component of the pressure. An illustration of this problem is shown in figure 7-22. The design and use of bonding tools is covered in section 9.0.

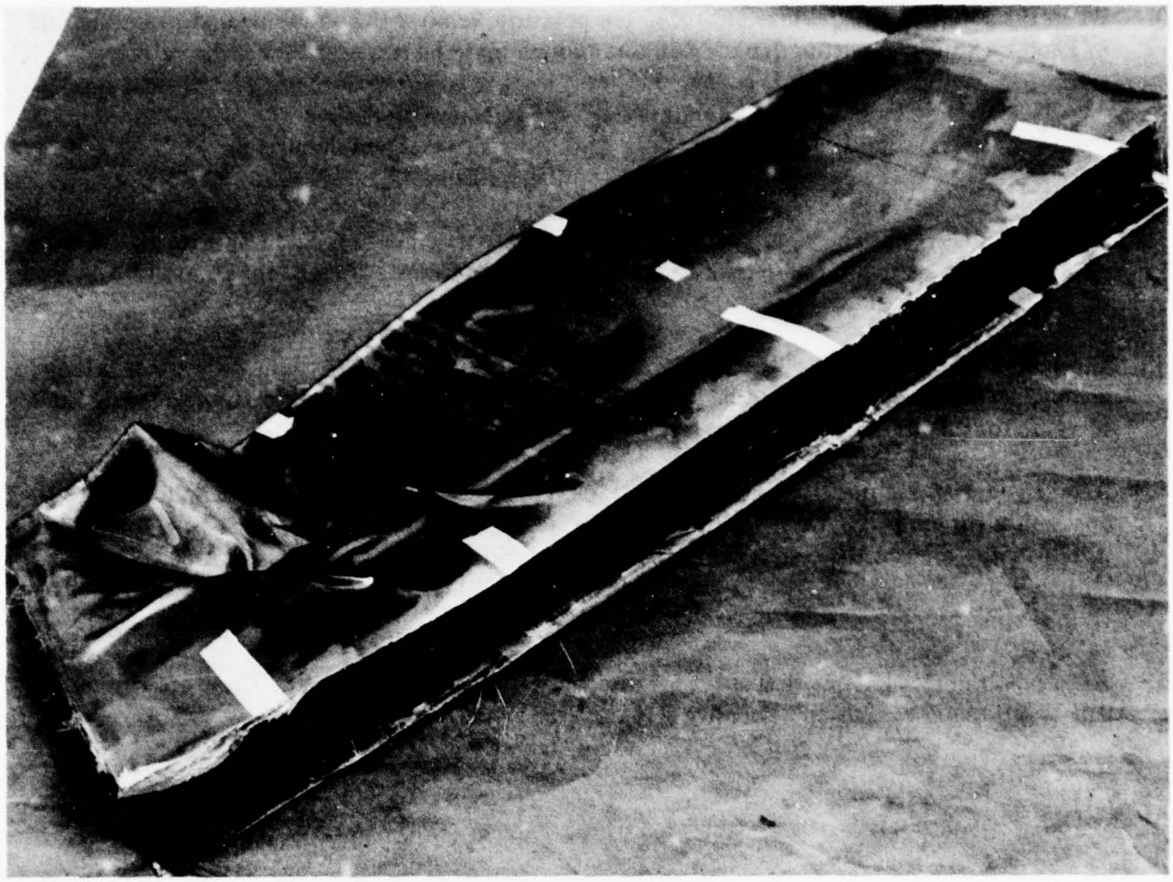


Figure 7-22.—Wedge-Shaped Panel That Collapsed in Autoclave Due to Inadequate Tooling Support

An outline of the adhesive layup and assembly of the details for cure is as follows:

1. Assemble all details in one location. This should be in a clean controlled area room per MIL-A-83377 especially constructed for the application of adhesives and detail lay-up.

2. Remove the adhesive from low temperature storage. Record the time removal. Allow the adhesive to reach room temperature before unsealing the packaging. This conditioning eliminates the condensation of moisture onto the film. Be sure the proper adhesive is selected.

CAUTION: Handle the Adhesive and Cleaned Core Details With Clean Lintfree White Gloves Only. Handle the Cleaned Metal Details By the Edges. DO NOT Touch the Cleaned Bond Surfaces. Contaminated Surfaces Must Be Recleaned Prior to Bonding.

3. When the adhesive has stabilized at room temperature, remove the wrapping and place the roll in a roll rack or on a cutting table. Roll out enough material to cover the faying surfaces.

   NOTE: Observe which detail faying surface is best to receive the adhesive application. Use those surfaces and details as cutting templates for the adhesive film.

   After the adhesive has been cut and ready for assembly, repackage the adhesive roll, seal the package to eliminate air, and return to low temperature storage. Record the total out time and subtract from the adhesive life.

4. Use a similar handling procedure for the core-splice adhesive. Cut the foam adhesive 1/8 inch wider than the core thickness to be spliced. Use a straight edge to hold down the adhesive and to guide the cut. Cut enough strips to cover the exposed core edge.

5. After the details are positioned against the tape, press the 1/8 inch of extra foam down into the core-splice gap until it is flush with the core surface. Take care so that the adhesive foam does not "roll down" into the splice gap as the details are slid into place. If this occurs, fill the gap with additional adhesive. Also be sure that this excess adhesive has not prevented the details from seating properly.

6. After positioning each detail, inspect for improper fit and surface height. These are common causes of bondline voids and porosity (see fig. 7-23).

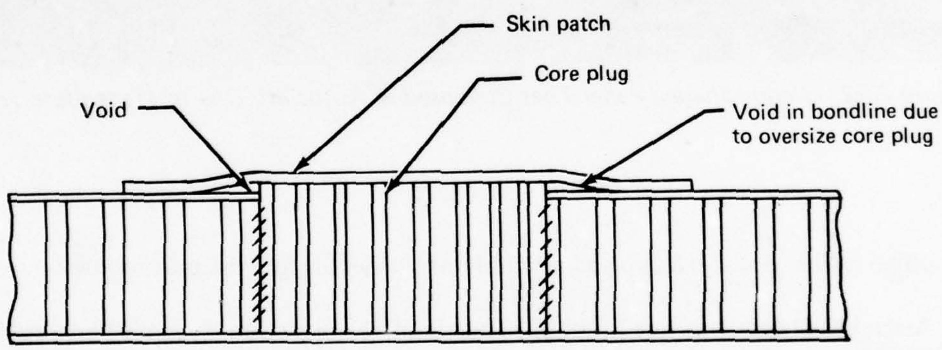


Figure 7-23.—Voids Under Metal Patch Plate Due To Improper Fit of Details

7. Complete the assembly by adding the appropriate layers of film adhesive and metal details. Secure in place with nylon film tape.

8. Install sufficient thermocouple wires to enable adequate monitoring of the assembly's cure temperature. Secure in place with nylon film tape similar to above.

9. Complete the bagging procedure as described in section 7.11.

7.11 VACUUM BAGGING TECHNIQUES IN PREPARATION FOR THE CURE CYCLE

"Bagging" is standard terminology referring to the sealing of the repaired area by encapsulating it in an impervious plastic film. Consolidation pressure may then be effectively applied to the assembly either by pulling a vacuum on the sealed area or by pressurizing the part in an autoclave and venting the sealed area to the external atmosphere. For the vacuum cure, heating may be obtained with heating blankets or by placing the assembly in an oven. In the case of the autoclave, heating is integral with the system.

Where the equipment is available, the autoclave cure is recommended. The higher available pressures nominally provide a superior quality bondline. Pressures obtained by the vacuum method are in the range of 8 to 12 psi. As a comparison, honeycomb assemblies are typically cured at 35 psi in an autoclave. Laminates may be cured at much higher pressures. This varies depending upon the particular adhesive system and the part design.

Where an autoclave is not available, a satisfactory bond can usually be made using a vacuum procedure. (Some adhesives do not give satisfactory results with a reduced pressure cure.) Certain precautions need to be taken, however. The detail parts should fit well. Also, the tendency of the vacuum to laterally move the honeycomb cell walls must be recognized. In general, the following rules apply:

- LIMIT THE VACUUM PRESSURE ON PARTIALLY BAGGED HONEYCOMB COMPONENTS OR ON ASSEMBLIES HAVING LIGHT CORE AND SKINS TO 8 TO 9 PSI.

- A full vacuum may be used for envelope (i.e., fully) bagged assemblies that have thick skins and heavy density core.

- When the assembly is to be left under vacuum for an extended period of time, for example over night, reduce the pressure to 5 to 6 psi.

- When vacuum is applied to an assembly to be cured in autoclave, as the autoclave pressure is raised to 5 to 10 psi, release the vacuum on the assembly by venting it to the exterior atmosphere.

There are several approaches that may be taken to bag the part. If the area being repaired is small and the part quite large, it may be easiest to seal only the area around the repair. In other instances it may be necessary to envelope bag the entire part. This may or may not be done in conjunction with a bonding tool. Approaches to the bagging process are described in paragraphs following a description of nomenclature. The following terminology is generic to the bond cure process and will be used in the subsequent discussion.

Bagging: The application of a specific group of materials necessary to seal off a repair area from ambient environment. This procedure is essential to obtain a bonding pressure. This is achieved by drawing a vacuum or pressurizing the assembly in an autoclave.

Bagging film: An impervious plastic film (e.g., nylon, PVC, Mylar, PVF, etc.) that covers the repaired area or completely envelopes the entire assembly. It is usually 2 to 4

mils in thickness and is discarded after each cure cycle because the plasticizers in the film are affected by heat, causing cracking and leaks.

Bleeder cloth:	A porous cloth used to allow passage of air or gases and to absorb excess adhesive flash. Air and gases flow over or around the assembly or repair to any provided outlet, such as vacuum probes or vacuum bayonets, which may be open to the atmosphere (as used in autoclave curing).
Bond assembly jig:	This is the tooling used to support the detail parts in proper contour during the bonding process. Commonly termed "BAJ."
Bridging:	A condition in which bagging materials, bleeder cloths, or plastic films are unsupported because of fit, gaps, or spaces. These areas should be plugged, filled, or covered with sheet metal, aluminum tape, or caul plates to eliminate any possible situation in which a "bag break" might occur.
Caul plate:	A support plate that is used to distribute pressure. It may be used over a thin skin that otherwise might dimple into the core cells. It may be used to bridge over an area where pressure is not desired. It may also be used with the assembly tool to fix the part details in place.
Fairing:	The matching of tool and part to eliminate misalignment that can cause cracks, gaps, or openings instead of a smooth transition from one surface to another. Each layer or ply of release film, bleeder cloth, plastic film, etc., should be rolled or stretched to a flat, smooth surface. Extrusions, protrusions, or fittings should be protected by fairing bars, metal blocks, or channel filler bars. End closure ribs should contain filler blocks of the same configuration to reduce pressure and to create a smooth transition to the tool surface (see sec. 9.0).
Hard tooling:	Well-built tooling made for continuous use and high production.
Release film:	Thin films produced from nonstick materials, such as FEP, teflon, modified halohydrocarbons, PVF, etc. They are interleaved between any adhesive film, resin, potting compounds, or sealant and a surface not intended to be bonded.
Soft tooling:	Inexpensive, short life tools that will maintain contour for a limited number of cycles.
Vacuum probes:	A probe that provides air passage through the bagging film. It provides a hose connection for the vacuum line. A number of probe designs exist and are commercially available (see sec. 8.6). Normally the probe base is under the bag film and a rubber or silicone disc on the exterior surface acts as a seal (see fig. 7-24). A bayonet-type probe is made of copper tubing, fitting, and bleeder cloth which extends under the bagging material (fig. 7-25).

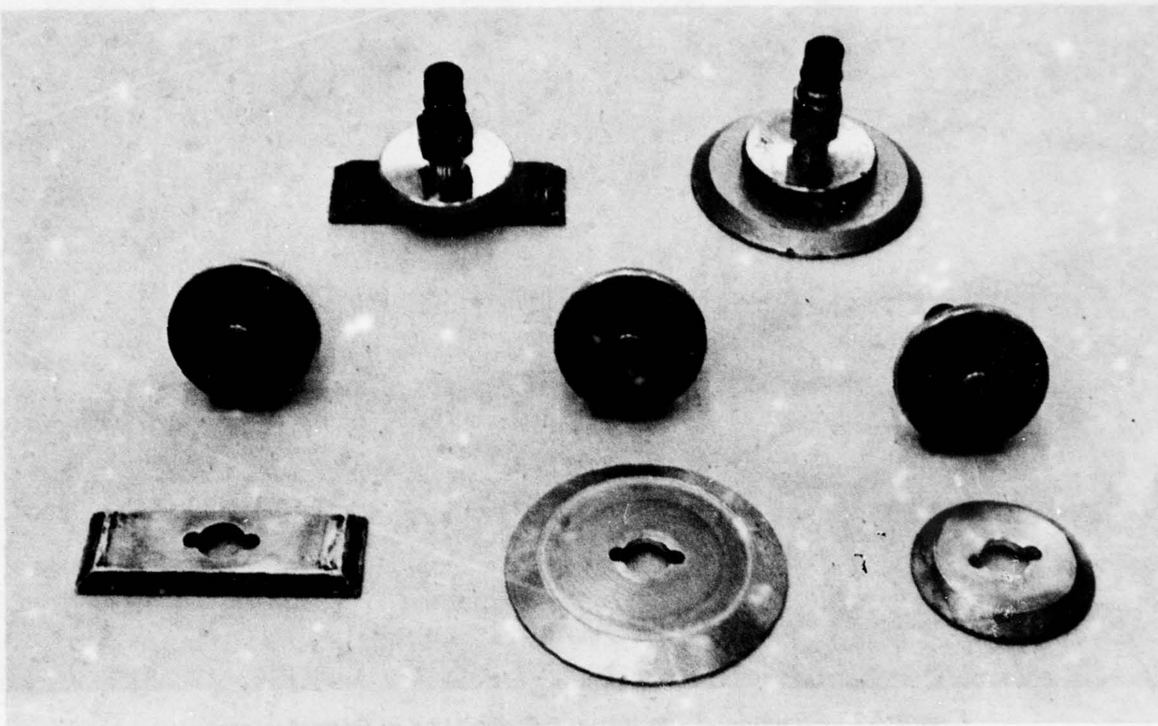


Figure 7-24.—Types of Flat Vacuum Probes

Vacuum seal putty: A semi-cured plastic material having tackiness for holding and sealing the bagging film during the cure cycle. This is the sealing medium between the nylon bag film and the tool base.

7.11.1 VACUUM BAGGING SEQUENCE

The bagging sequence begins after the repair details have been assembled and fixed in position and the thermocouples have also been attached in place. If convenient, the component may be positioned on a table for easy access. Remove materials that have been applied temporarily to prevent corrosion or contamination. Recheck the visible repair details for proper fit and location.

Position and pin the fairing bars in place. Secure with nylon plastic film tape. Apply folded pieces of bleeder cloth over any sharp corners or edges to prevent cutting or breaking the nylon bag film.

Proceed with the bagging operation as described in the following steps. A cross-section of a small repair bagged for cure is illustrated in figure 7-26. Figure 7-27 illustrates a component being bagged in a bond assembly jig (BAJ). Purchase descriptions for equipment are included in section 8.6.

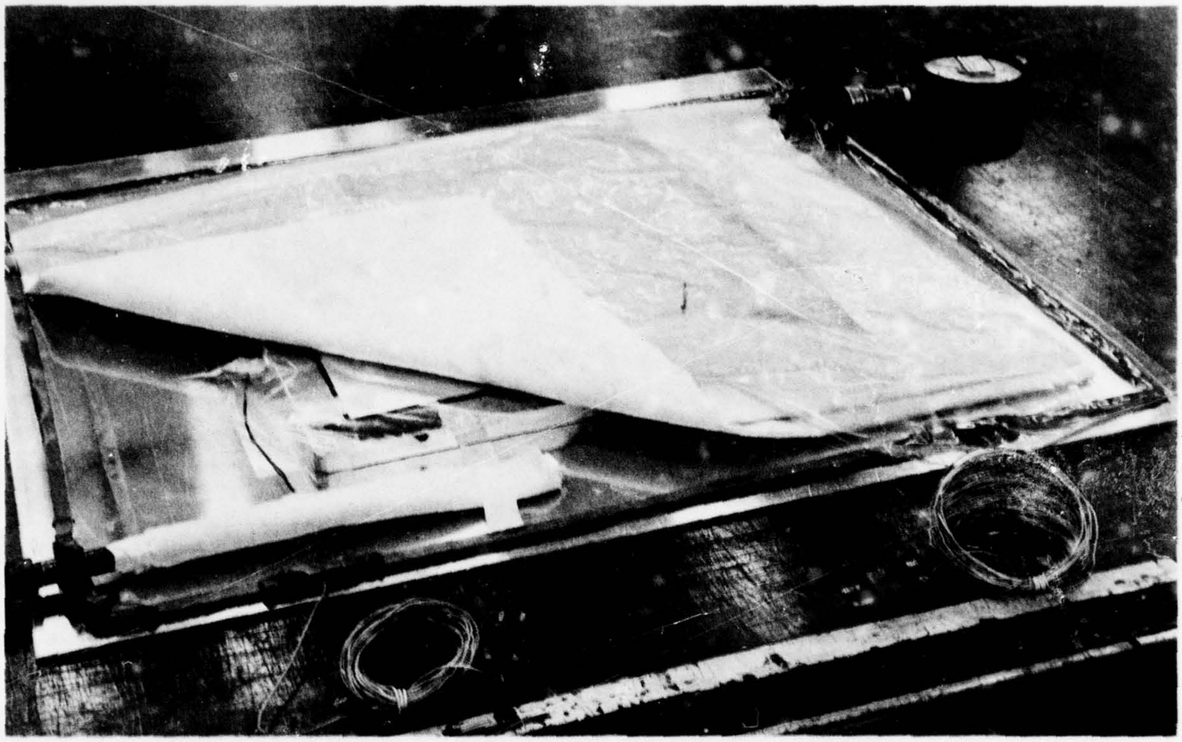


Figure 7-25.—Bayonet-Type Vacuum Probe Used in Bond Assembly

1. Apply release film over the area where the adhesive flash or bleed-out may otherwise contact the other bagging materials. Release film materials are listed in table 4-5.

2. If a heating blanket is to be used, apply a layer of PVC- or TFE-coated fiberglass cloth over the release film to act as a separator to protect the release film and to give more uniform heat distribution. Identification of the fiberglass cloth is given in table 4-5. If another method of heating is to be used, proceed with step 4.

3. Before installing the heating blanket, check it for broken leads or burned areas. If it is acceptable, position it over the PVC fiberglass cloth. Secure both the fiberglass cloth and blanket in place with high temperature masking tape.

   NOTE: The heating blanket should be a minimum of 4 inches larger than the largest dimension of the repair detail to provide even heat distribution.

4. Add 4 plies of bleeder cloth over the heating blanket or release film. Extend this approximately 4 inches on a minimum of two sides for location of the vacuum probe pads. The bleeder cloth allows free flow of air over the intire area. It also absorbs any excess resin that may bleed through or around the release film. The bleeder cloth is identified in table 4-5.

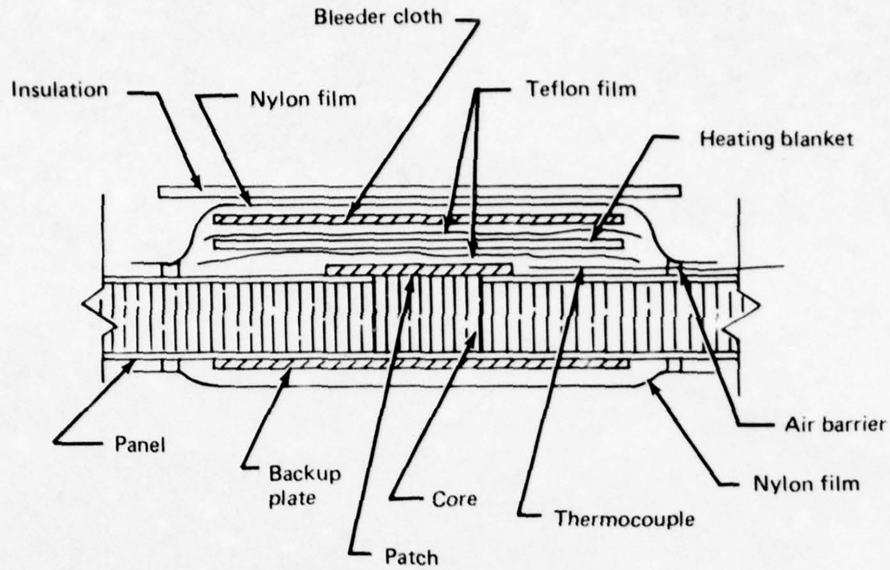


Figure 7-26.—Cross Section of Repair Bagged for Cure

5. Form an air barrier around the repair using vacuum seal putty. Place the heater leads and thermocouple wires on top of the seal putty. Use short strips of putty to seal each lead as shown in figure 7-28. The vacuum bag will seal to this putty barrier. If a bayonet-type vacuum probe is used, place it in position before the bagging film is applied.

6. If base-plate-type vacuum probes are used (fig. 7-24), position these on the edge areas provided by the excess width of bleeder cloth (see fig. 7-29).

   NOTE: DO NOT put the vacuum probe on bare metal.

   Separate the top half of the probe from the base and set aside for later installation. If the surface is sloping, hold the base in position with high temperature masking tape. A minimum of two probes should be used for the first 8 square feet of area plus one additional probe for each additional 8 square feet.

7. Cut a piece of bagging film that is large enough to cover the repair area. Cover the area and seal with the vacuum seal putty. Start sealing of the nylon bag film at the center of assembly and work in both directions to seal the nylon bag. Leave excess material for pleats and slack when the bag is under pressure. Push all areas of the bleeder cloth and bag down against the fairing bars and tool face.

   NOTE: Use special precaution when sealing around the heater or thermocouple (T/C) leads, as most leaks occur at these points.

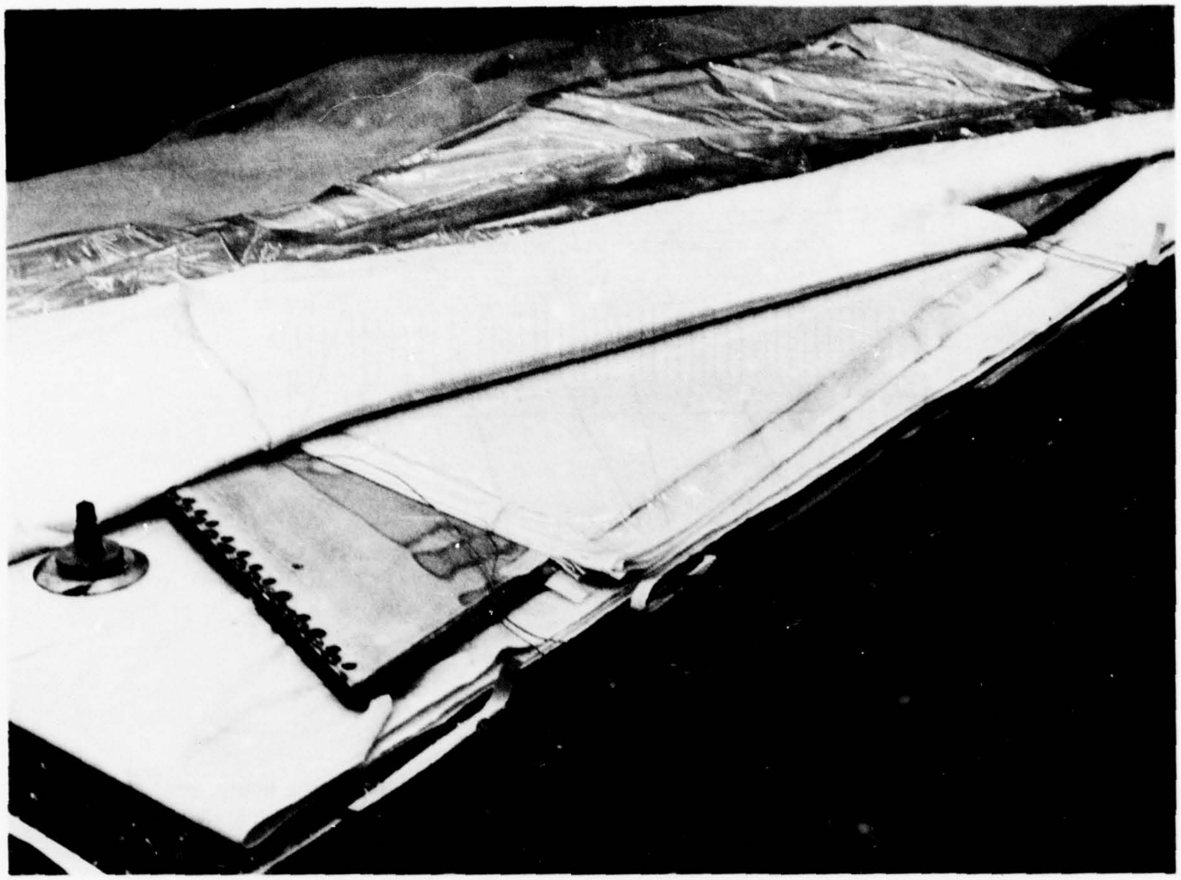


Figure 7-27.—Component Being Bagged in Bond Assembly Jig

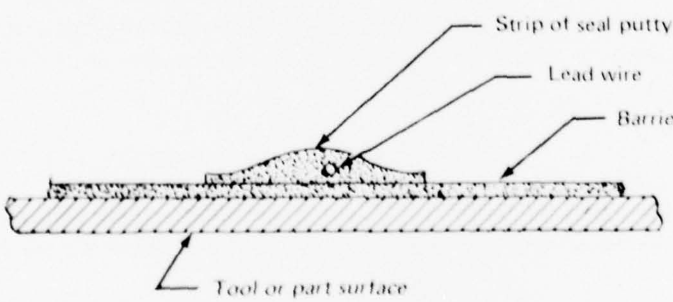


Figure 7-28.—Use Strips of Putty to Seal Around Heater and Thermocouple Lead Wires

Figure 7-29.—Vacuum Probes Positioned on Bleeder Cloth at Edge of Assembly

8. Cut a cross in the bag film to allow the neck of the vacuum fitting to protrude. Install the elastomer seal and the knurled cap.

9. Attach a vacuum hose to one probe and a vacuum gage to the other as shown in figure 7-30. Adjust the aspirator pressure to 16 to 18 inches (8 to 9 psi). Check for leaks. Reseal as necessary to obtain a maximum leakage rate of 1.0 inch Hg per minute. The bagged repair is now ready for cure.

10. Connect the thermocouple wires to a pyrometer. Check to ensure that each thermocouple wire is recording.

11. Connect heater and vacuum leads as required. Place in the oven or autoclave for cure or cover the bagged area with heating blankets and layers of insulation.

Figure 7-30.—Checking the Vacuum Assembly for Leaks

12. Apply heat and pressure. Monitor these to achieve the curing requirements for the particular adhesive as noted in section 4.2. If the cure is made in an autoclave, when the positive pressure reaches 10 psi, vent one half of the vacuum lines to the exterior atmosphere. Pressure monitoring the other vacuum lines will indicate any abnormal pressure build-up under the bag film. If the cure is made using vacuum pressure, continually monitor the gages for leaks. If any gage shows excess vacuum loss before the temperature reaches 150° F, the curing procedure can be discontinued, the bag resealed, and the cycle restarted.

13. After the cure is complete, cool to 180° F before relieving the pressure. Remove all bagging materials.

WARNING: WEAR HEAT INSULATING GLOVES WHEN HANDLING HOT TOOLS AND ASSEMBLIES.

7.12 FLASH REMOVAL AND CLEAN UP

1. Remove excess adhesive, stuck tape, etc. with a sharp tool (1/4-inch-wide wood chisel, extra sharp). Take special care not to damage the metal surfaces.

2. Wipe away dust and chips with a clean dry cheesecloth pad.

7.13 POST INSPECTION

1. Conduct post repair inspection as noted in section 10.1.7.

7.14 SEAL AND FINISH

1. Seal per section 4.3.6 and finish per section 4.3.7 and the applicable aircraft T.O.

8.0 TOOLS, EQUIPMENT AND FACILITIES

Certain tools, equipment, and facilities are especially useful to the bonded structure repair process. Some of these are described in this section. A listing of procurement sources is given in section 8.5. Tools or equipment for nondestructive inspection are included in section 10.0.

8.1 TOOLS FOR DAMAGE REMOVAL

8.1.1 HIGH-SPEED ROUTER

The high-speed router illustrated in figure 8-1 is one of the most versatile tools for damaged material removal. It may be used for the removal of both skin and core material. A carbide bit is required for routing titanium. The router is commonly used against a template to define a smooth cut. An appropriate set-back distance is allowed to compensate for the width of the router collar.

The router may be either hand held or used with a supporting base plate as shown in figure 8-2. The base plate typically incorporates a threaded lock ring that is rotated to adjust the depth of cut. It is then locked in position with set screws.

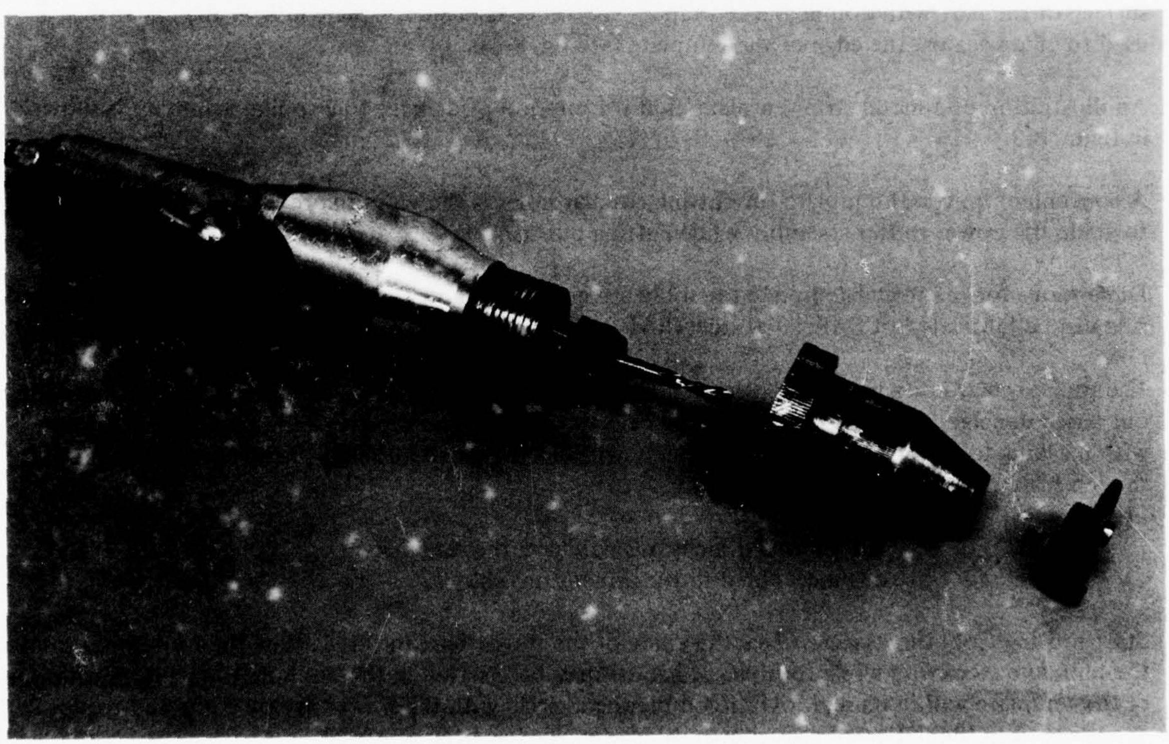


Figure 8-1.—Portable Air-Driven High Speed Router

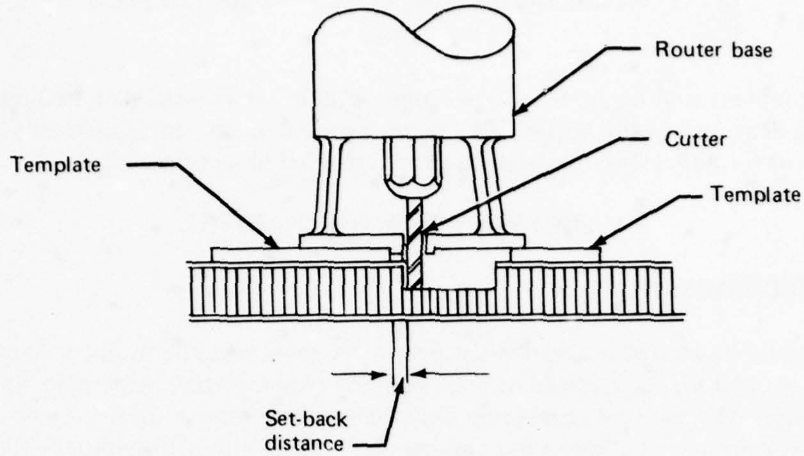


Figure 8-2.—Typical Router Setup With Template

Router Templates

Simple router templates may be made of metal, plastic, or plywood. The template is attached to the surface of the part with double-backed tape. Allowance is made for the width of the collar that is used to guide against the edge of the template (see fig. 8-2).

An illustration of a metal strip template used for removal of damage.to a spoiler assembly is shown in figure 8-3.

A convenient universal template for cutting circular holes is shown in figure 8-4. The template is used to guide the power router assembly while cutting out damage with a 1/4-inch router bit.

Dimensions for the router template assembly are given in figures 8-5 and 8-6. Both the template and ring can be fabricated of SAE 1010 steel (SAE 1015, 1020, ASTM A7-50, or AISI C-1018 optional).

The four circular holes in the template can be used to rout holes up to 1.25-inch diameter. To rout out larger damage, center the template ring over the damage and tape it to the honeycomb panel with masking tape. The template turns freely within the ring. The heads of the two screws prevent the template from coming out of its seat.

> NOTE: All internal dimensions will have the set-back distance added to the dimensions shown.

Start routing from the center. Place the guide of the router base in slot 1, start the router and rotate the template clockwise while routing. A handle may be inserted in the tap hole to facilitate rotation of the template within its seat. After completing a circle with the router in slot 1 proceed to slot 2, 3, and so on in the indicated sequence until all damage has been removed.

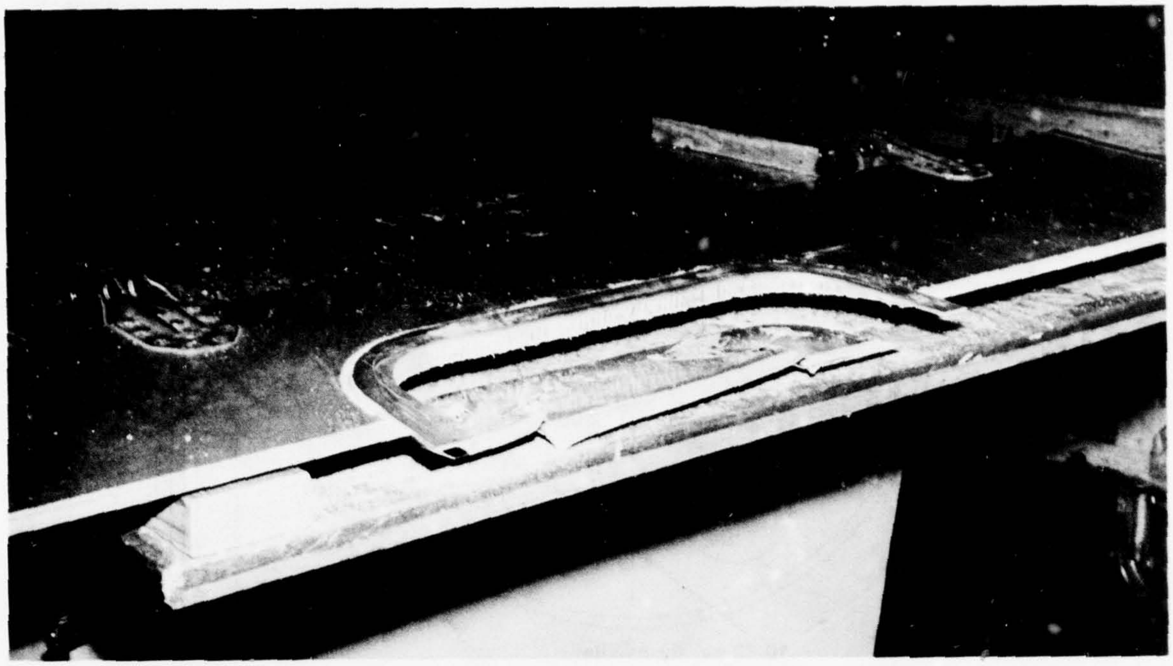


Figure 8-3.—Metal-Strip Template Used as a Router Guide to Remove Damage from a Spoiler Trailing Edge

Figure 8-4.—Air-Powered Router and Variable Diameter Router Template

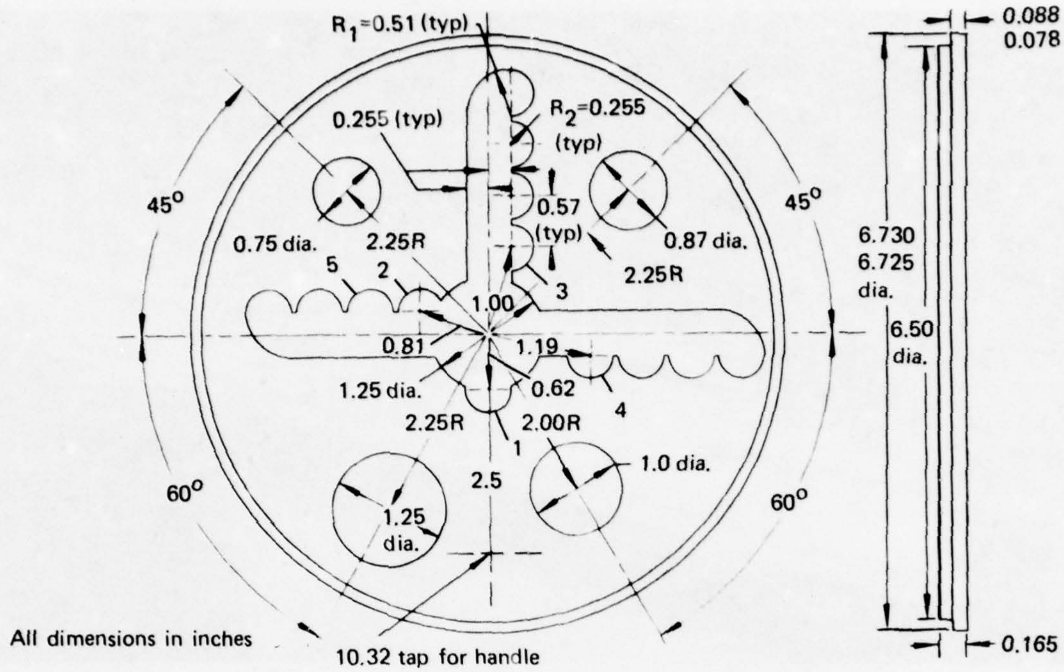


Figure 8-5.—Router Template Assembly Component—Rotating Plate

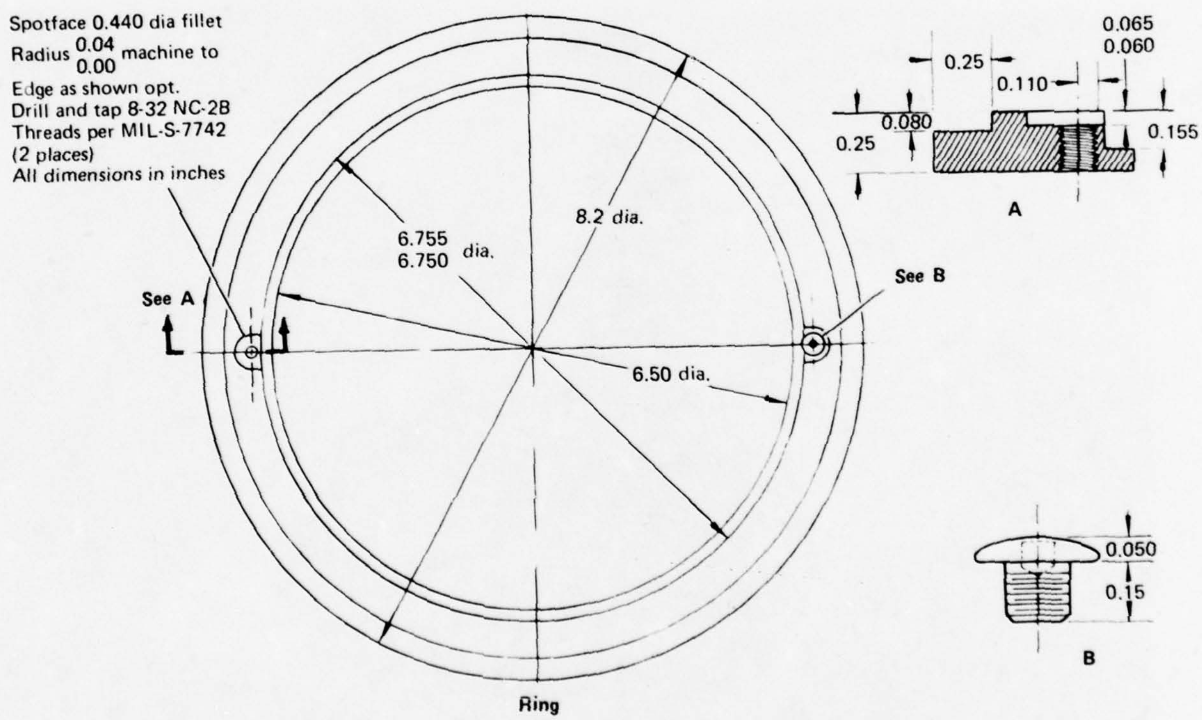


Figure 8-6.—Router Template Assembly Components—Support Ring and Lock Screw

8.1.2 HOLE SAW AND FLY CUTTER

A hole saw and guide bushing are illustrated in figure 8-7. The saw is used advantageously to cut 1.00- to 4.00-inch diameter holes in aluminum or titanium sandwich faces. Where the cut is to be extended into the core, use of the router is preferred. The hole saw tends to tear the core.

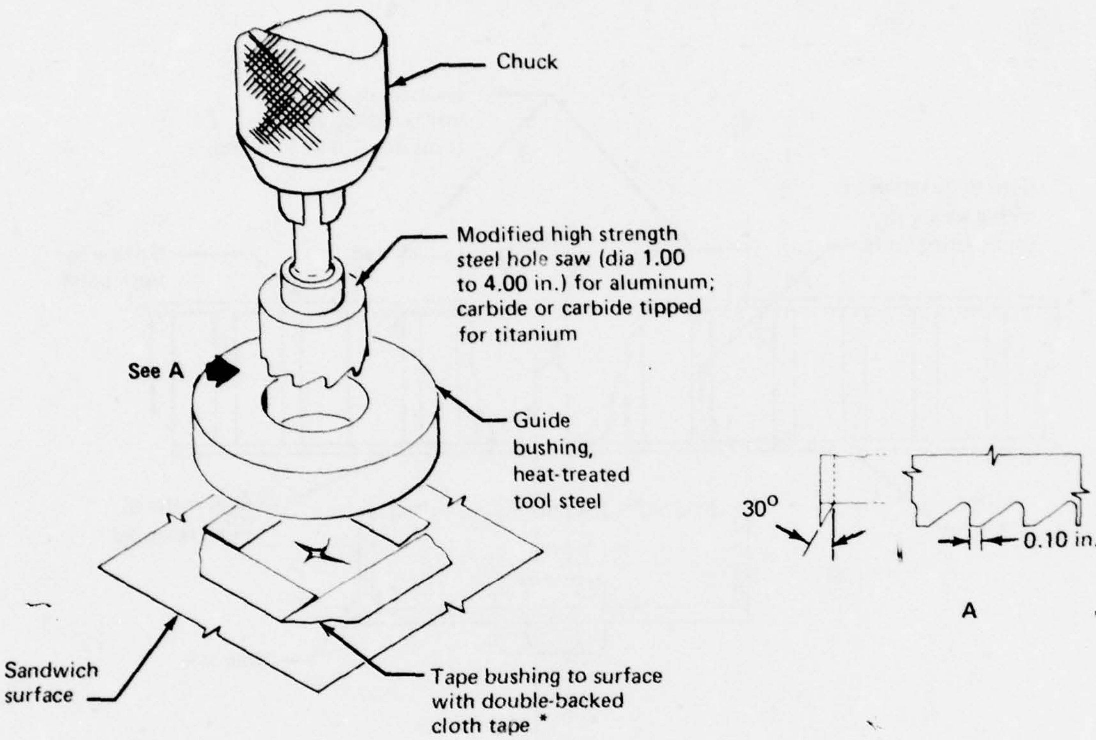


Figure 8-7.–Hole Saw and Guide Bushing for Removing Sandwich Skin Material

The saw may be either power or manually operated. It is typically guided by the use of either a pre-drilled pilot hole or by a guide bushing. The use of a pilot hole is convenient when concentric holes are to be cut in opposite sides of a sandwich panel. The guide bushing is locally made from 0.75-inch-thick tool steel. The inside diameter of the bushing guides the blade while allowing it to turn freely.

The bushing is attached to the sandwich surface with double-backed tape. The saw is used to cut through the solid metal only, i.e., through the skin or skin laminate combination (see fig. 8-8) subsequent removal of the core is done either with a high speed router or a core-cutting knife.

WARNING: WEAR A FACE SHIELD OR SAFETY GLASSES WHILE USING THIS EQUIPMENT.

The operation may be performed similarly with a fly cutter shown in figure 8-9.

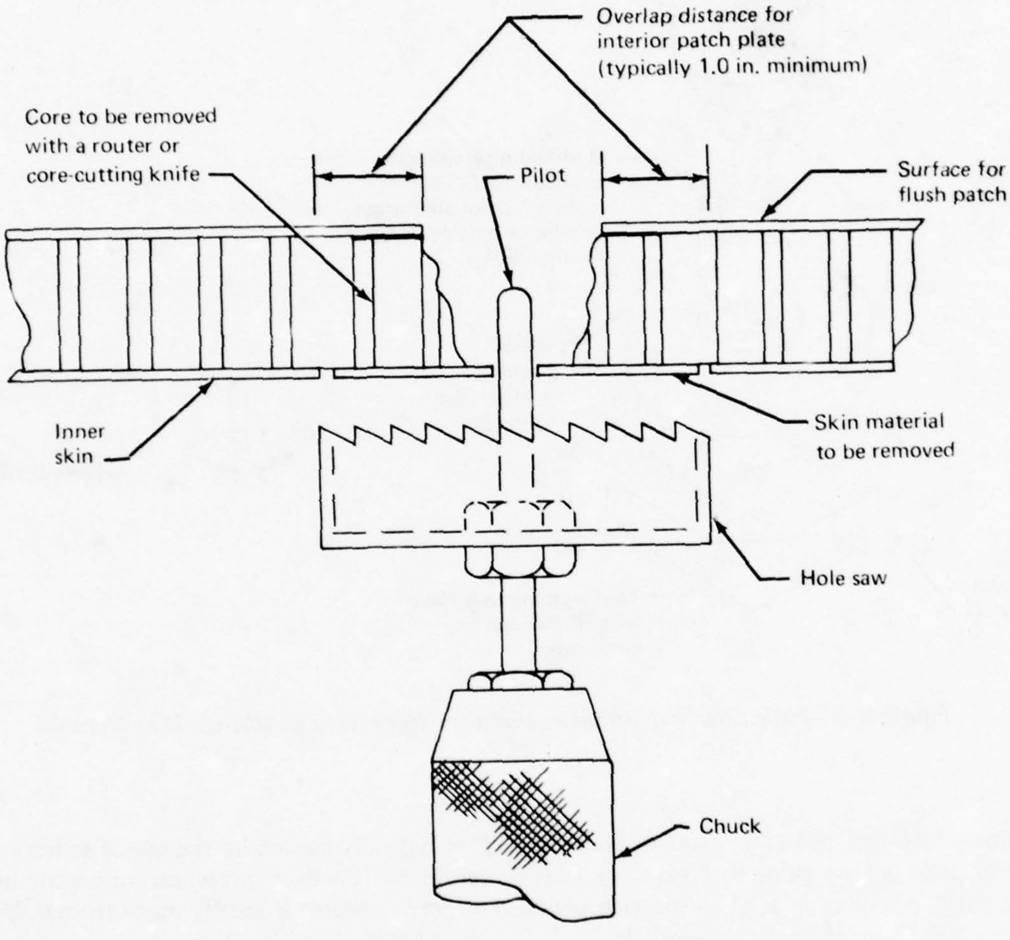


Figure 8-8.—Removal of Skin Using a Pilot Hole as Hole Saw Guide

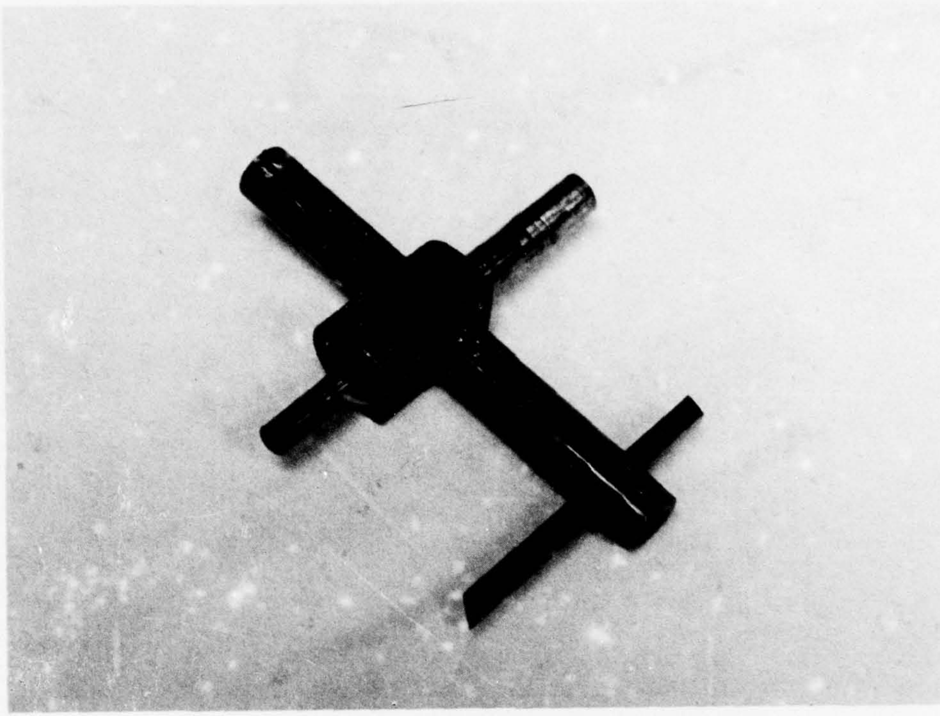


Figure 8-9.—Fly Cutter Used to Remove Skin Material for Repair

8.1.3 PORTABLE SAWS AND SANDERS

The reciprocating and circular saws, shown in figures 8-10 and 8-11, are especially useful for cutting the metal skin as well as the heavier metal pieces such as stiffeners or fittings (see section 8.5 for supplier listing).

Another piece of equipment that is very useful is the high speed air motor with a sanding-disk attachment. This, as well as other attachments, is shown in figure 8-12. The sanding disk is especially useful for smoothing the surface after pieces of core have been removed with a core-cutting knife or other means. It may also be used for removing the heavier density core as shown previously in figure 7-9.

8.1.4 SKIN PEELING TOOL

A tool that facilitates peeling of the sandwich skin and doublers is shown in figure 8-13. The tool is used similar to a sardine or coffee can key. The edge of the skin is placed in the tool slot and rolled up (see figs. 7-4a and b). For wide strips or for high peel strength adhesives, it may be necessary to cut the skin into strips with a tool such as the portable circular saw described in the previous paragraph.

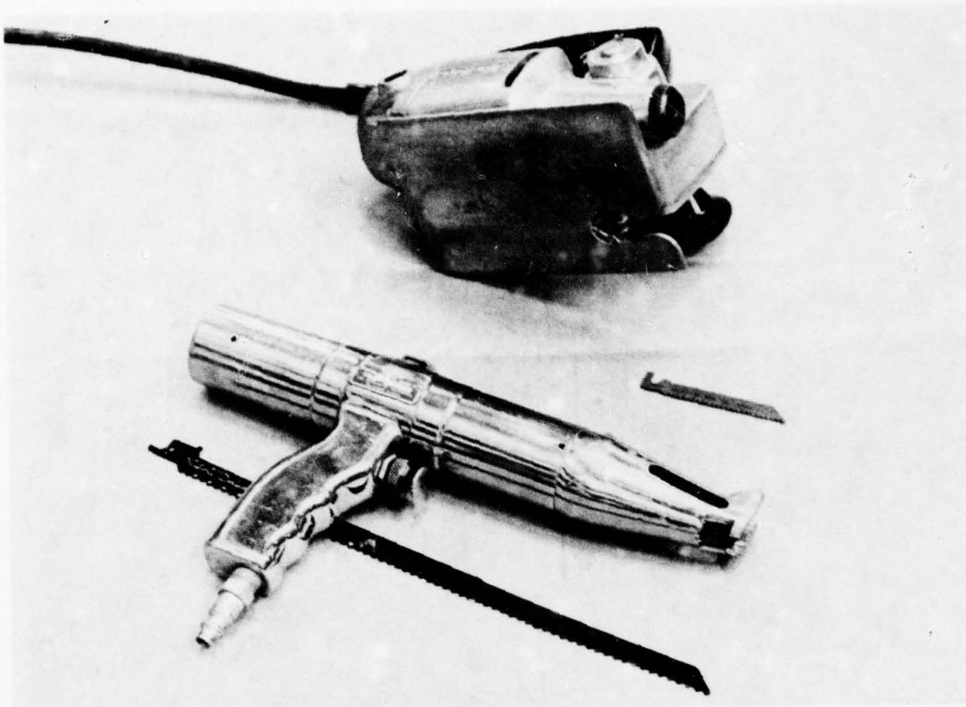


Figure 8-10.—Portable Reciprocating Saws

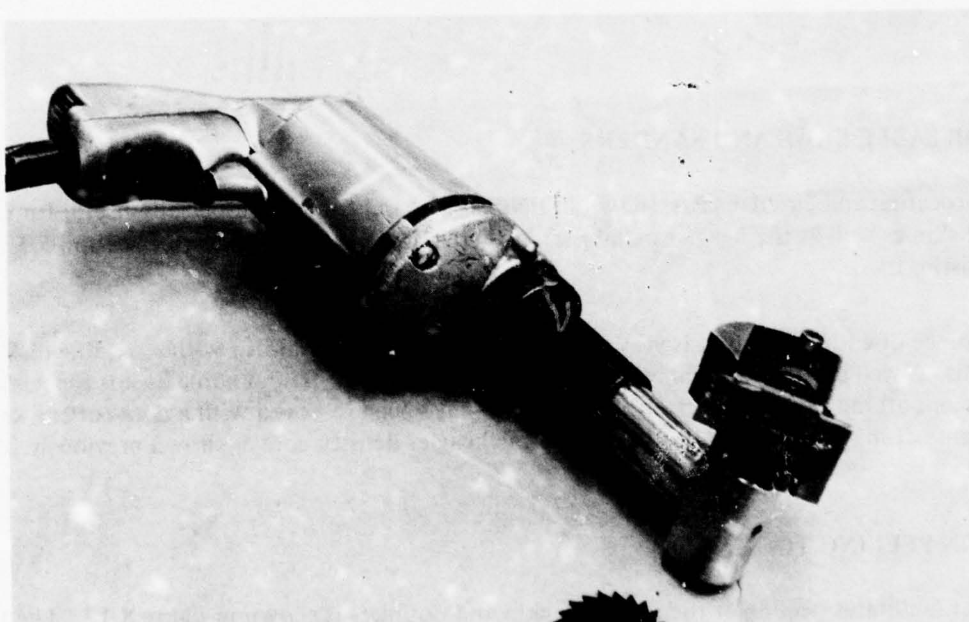


Figure 8-11.—Portable Circular Saw

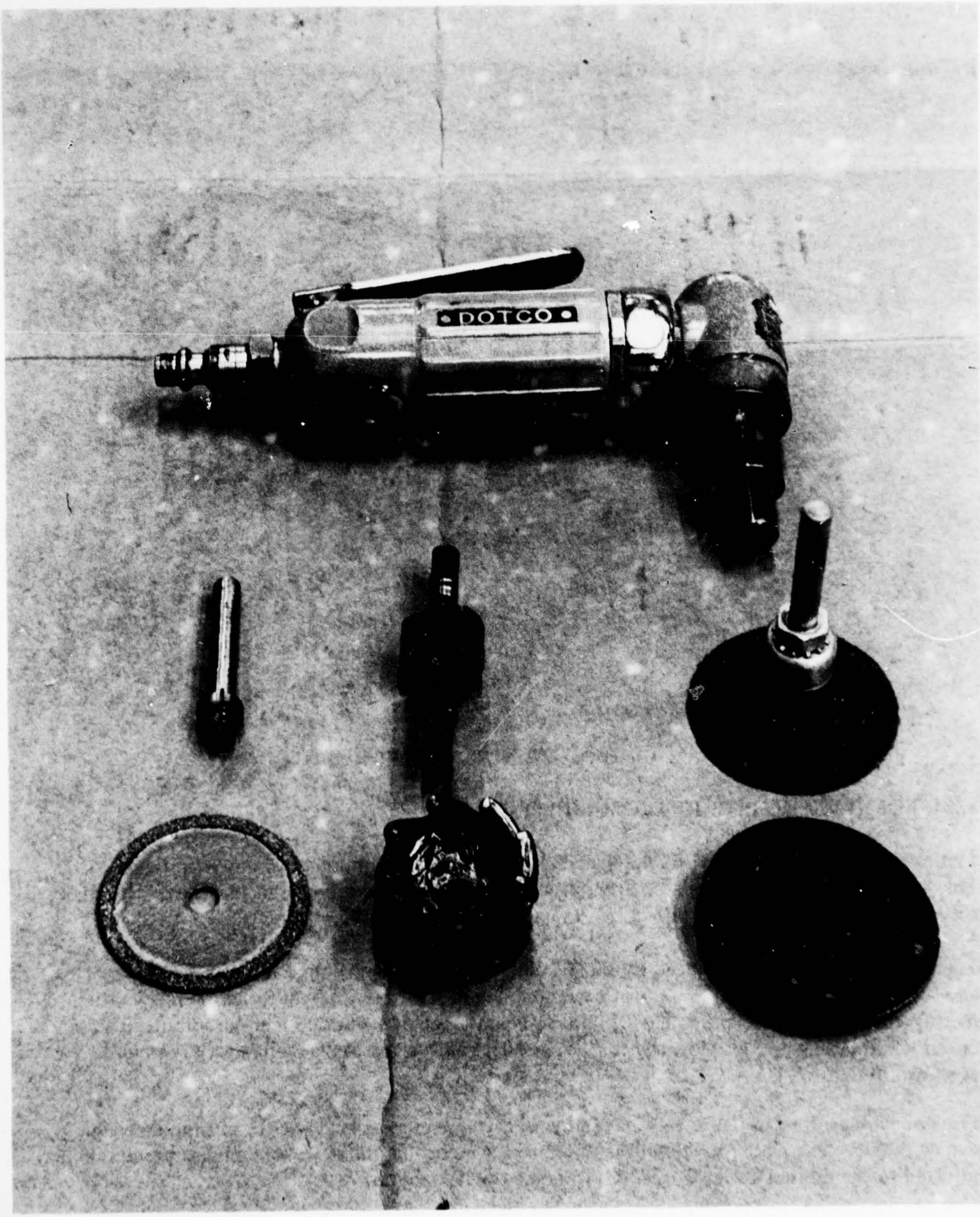


Figure 8-12.—High Speed Air Motor and Attachments

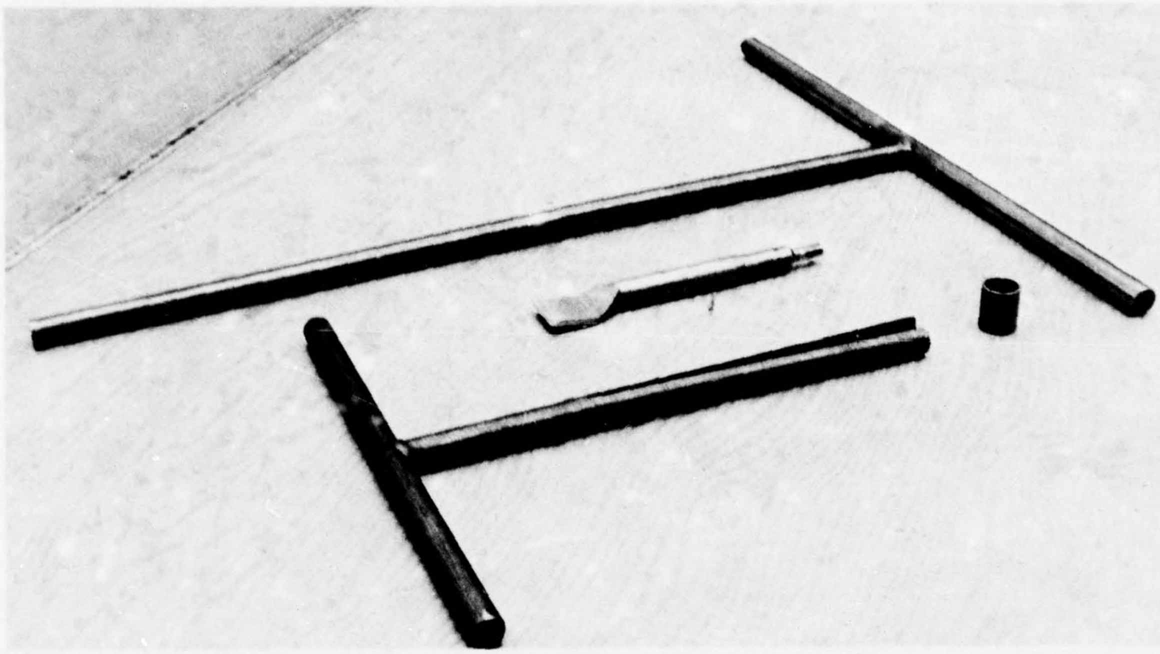


Figure 8-13.—Skin-Peeling Tools

8.2 CORE MACHINING AND FORMING

8.2.1 EQUIPMENT FOR SURFACE MACHINING

Typical equipment for surface machining large pieces of honeycomb core is shown in figure 8-14. This machine has both longitudinal and transverse crossrails. The rail heights may be differentially adjusted to permit contouring or to permit tapering (as shown in fig. 8-15).

The machine uses a multiple speed (7000, 14 000, and 21 000 rpm) precision electric motor. This allows the operator to select a range of cutter diameters (1/2 to 3 in.) while maintaining a satisfactory cutter peripheral speed. The feed rate is maintained at 50 to 200 feet per minute. The cutter is the valve stem or "blogna slicer" type. These cutters are available in a variety of sizes, as shown in figure 8-16.

The sine plate, shown in figure 8-17, is used with the core-cutting machine for machining wedge-shaped details. The plate provides a vacuum face for mounting the core. The plate surface can be adjusted to the desired angle (0^o to 20^o) to make the tapered cut.

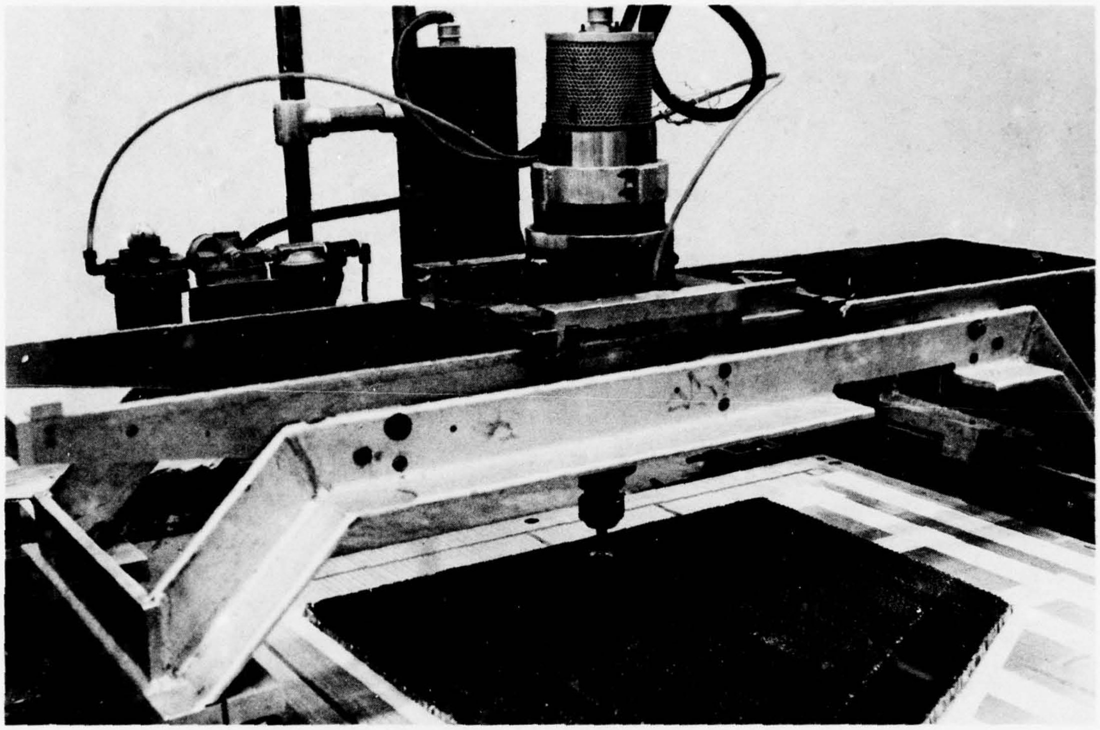


Figure 8-14.—Surface Machining Honeycomb Core

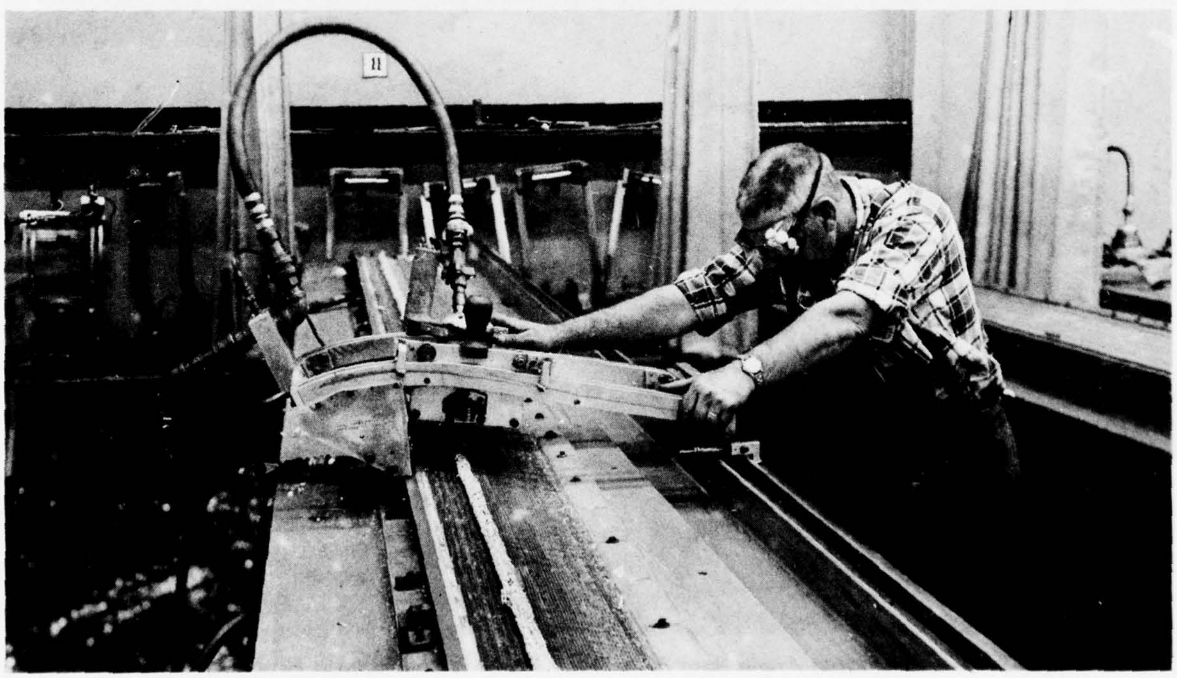


Figure 8-15.—Taper-Machining Honeycomb Core

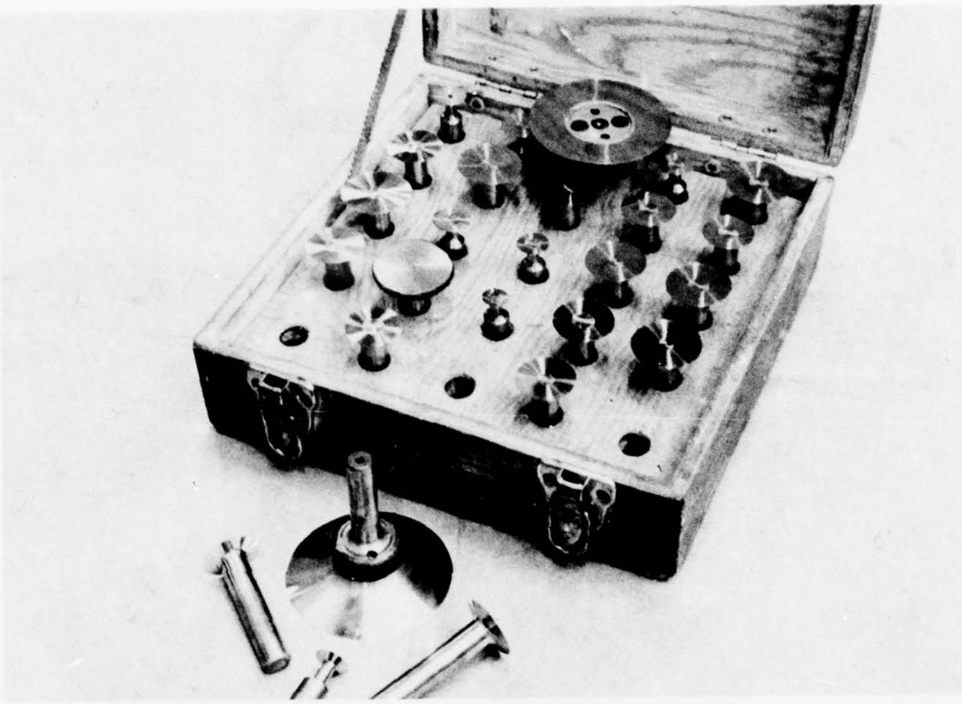


Figure 8-16.—Variety of Valve-Stem-Type Core Cutters

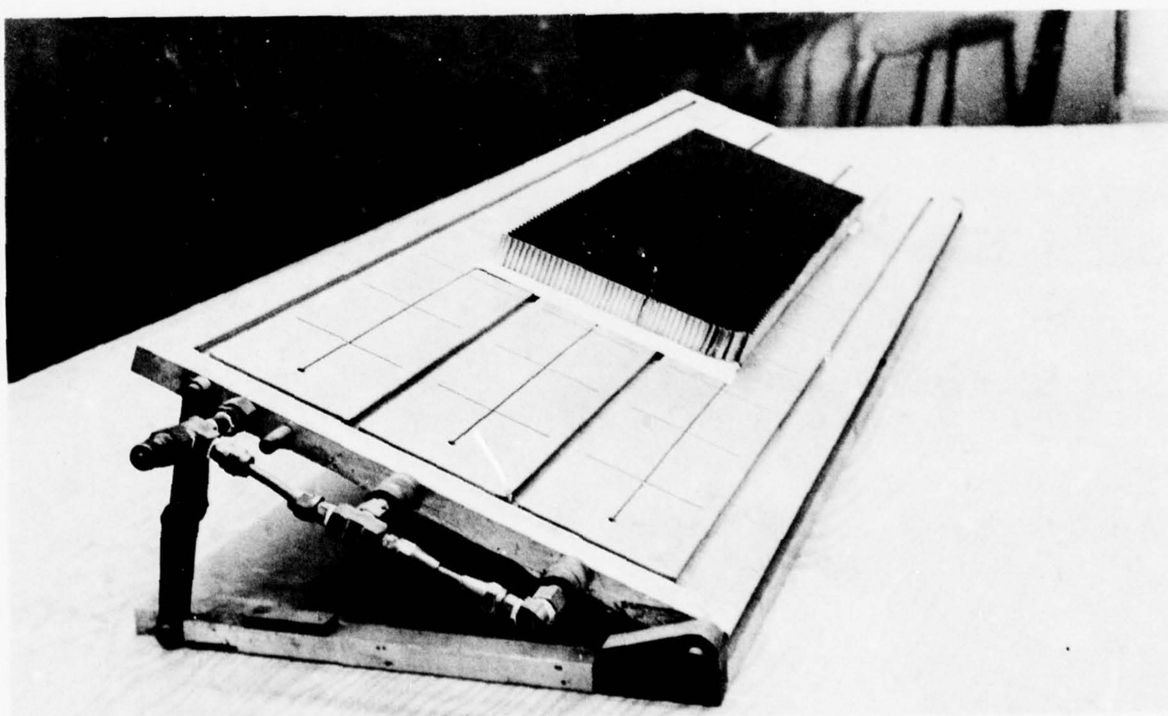


Figure 8-17.—Adjustable Angle Base Plate (Sine Plate) With Vacuum Hose Attachments for Securing Core

8.2.2 CORE-FORMING EQUIPMENT

The equipment necessary to prop—rly form core details is generally of special design and only available at the core fabricator's facilities. —nited core forming can, however, be done with selected sheet-metal-forming machines, provided proper procedures are used. Examples of usable machines are the Farnham pyramid roll or the "pinch" type plate roll. Core-forming with the Farnham roll is shown in figures 8-18 and 8-19. Additional information on core forming is included in section 7.6.2.

8.3 PROCESSING FACILITIES

Processing facilities should meet those requirements specified in MIL-A-83377.

8.3.1 SURFACE PREPARATION TANKS

The type of tanks required for the various surface preparation procedures are described in section 5.3.1. Parts progressing through a surface preparation tank line are shown in figure 8-20. Details such as the tank lining and solution temperature are listed for a typical system in table 8-1.

Solution makeup, operation, and processing procedures are given in section 5.3. Requirements that should be met concerning tank location and equipment are as follows.

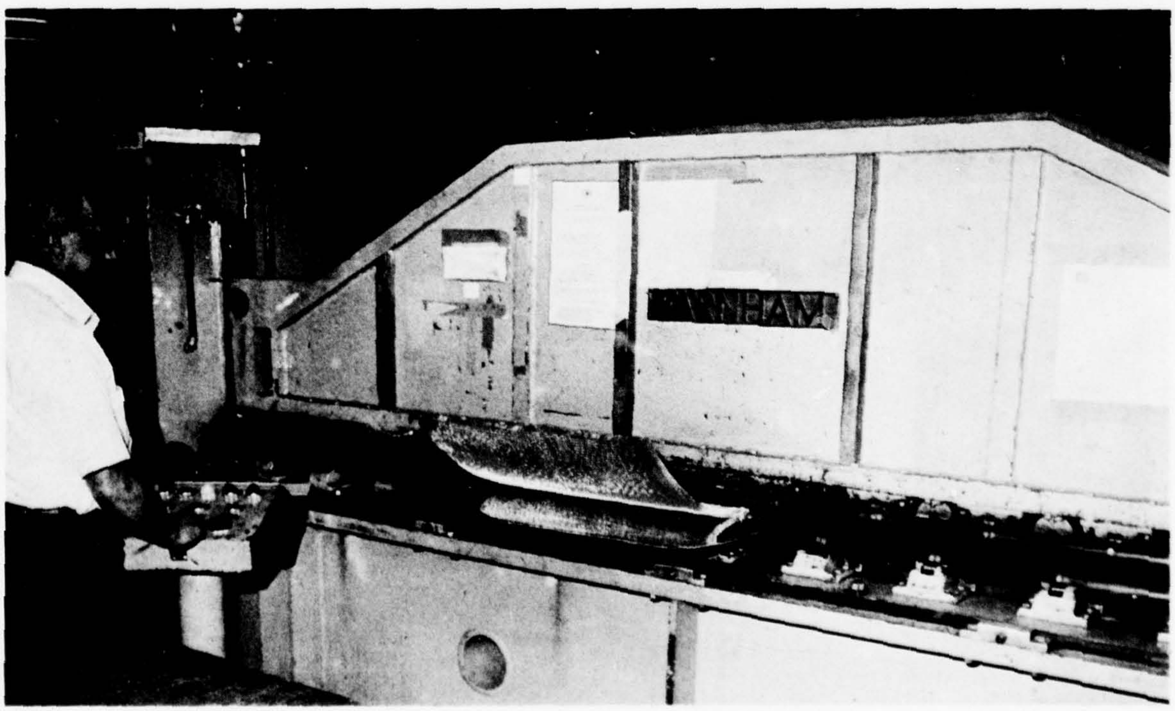


Figure 8-18.—Forming Honeycomb Core With Farnham Pyramid Roll

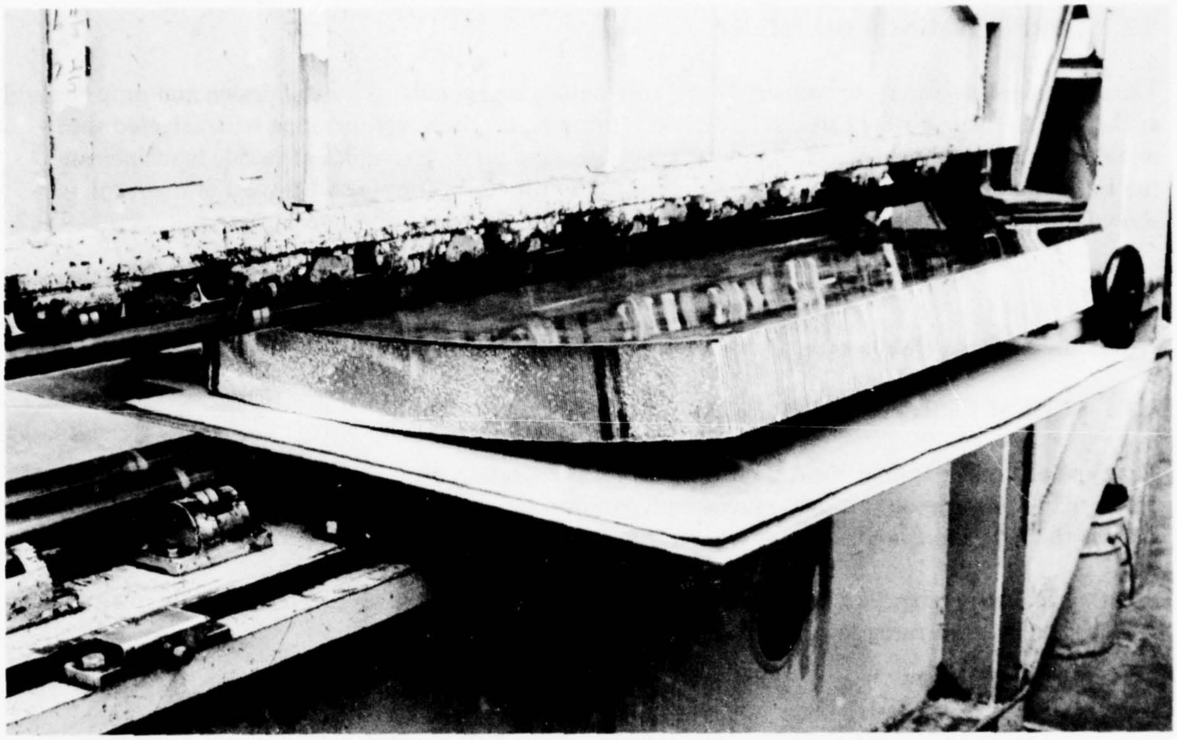


Figure 8-19.—Forming Honeycomb Core With Farnham Roll

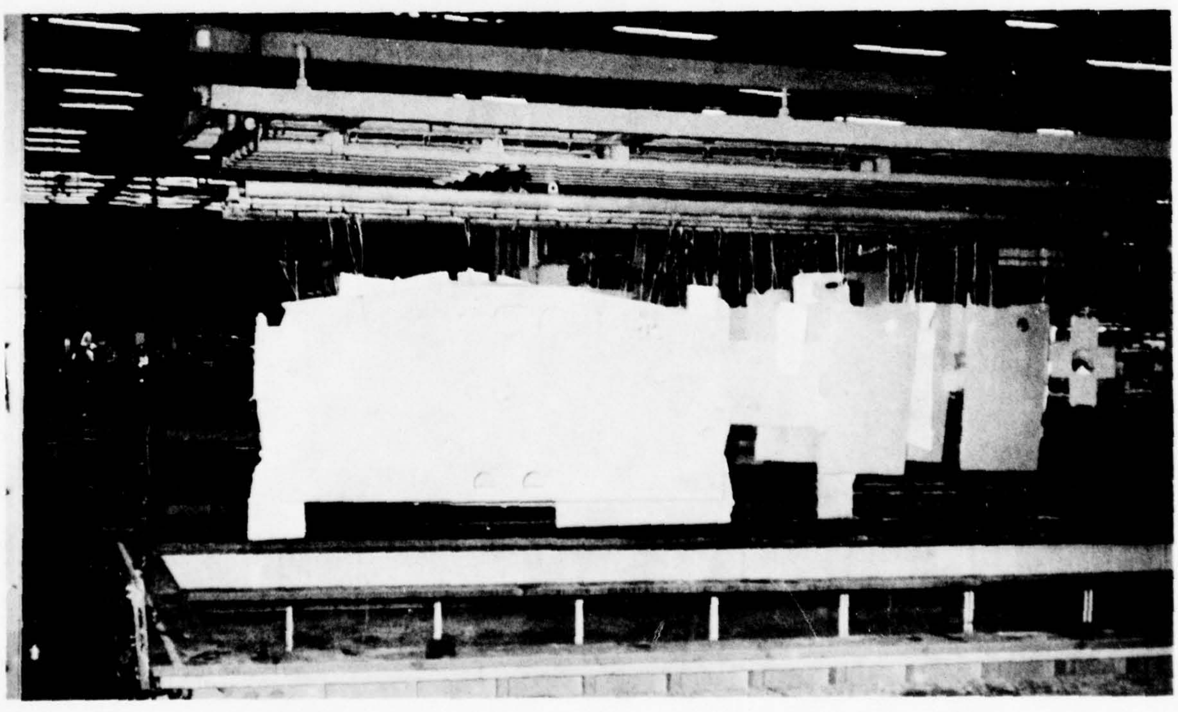


Figure 8-20.—Parts Progressing Through Surface Preparation Tank Line

Table 8-1.—Typical Surface Preparation Tank System

Function	Special tank lining	Temp, °F	Agitation	Vent	Remarks
Vapor degrease	None	188	—	None	Deactivated cover (DCCR)
Alkaline cleaner	Mild steel	140±5	Air	Push air	
Rinse	Vinyl paint	110	Air	None	DCCR
Deoxidizer	Lead	155±5	Air	Push air	Teflon heaters
1st rinse	PVC	Amb	Air	None	DCCR
2nd rinse	PVC	Amb	Air	None	DCCR
Phosphoric acid anodize	Stainless steel	Amb	Air	Ex	Phosphoric acid filter
Rinse	Vinyl paint	Amb	Air	None	DCCR, timed water flow
Dryer	None	140 max	—	None	

1. Locate surface preparation and drying facilities remote from other activities and/or equipment that emit contaminants detrimental to adhesion. These include but are not limited to dust, grease, oil, exhaust vapor, and parting agents.

2. Filters and/or traps shall be installed for removing airborne dust, moisture, and oil from all air lines used for solution agitation and drying of parts.

3. All tanks other than water rinse tanks to be operated at elevated temperatures shall:

   - Be equipped with automatic temperature indicating and regulating devices

   - Be air or mechanically agitated so as to minimize all temperature and concentration gradients. The maximum temperature gradient measured from the hottest to the coldest point in the tank shall not exceed 10° F

4. All instruments, gages, and regulators shall be periodically calibrated or tested within the time limit specified by the applicable T.O.

5. Air cleaning devices (e.g., drainage traps, cleaning separators, and filter cartridges) shall be inspected and serviced at frequencies necessary to assure meeting cleanliness requirements.

8.3.2 PRIMER APPLICATION AREA

After preparation of the metal surfaces, it is important that they are not touched, even with white gloves, until after the primer application. An overhead monorail system to which the parts can be suspended is one suggested method of providing a convenient means of transporting the parts for spray application of primer and for subsequent baking. The area used for spraying primer and baking should be pressurized and temperature controlled. Primer may be applied in a downdraft spray booth such as that in figure 8-21 or in an open-faced water wash booth.

The primer should be applied by a qualified spray operator to a specified film thickness. The primed parts are then air dried and placed in ovens for baking the primer film. The film thickness may be inspected with an eddy-current-type instrument called a "permascope." Other methods are the use of an isometer or a light section microscope.

8.3.3 CONTROLLED ATMOSPHERIC LAYUP AREAS

An example of an environmentally controlled adhesive application area is shown in figure 8-22. The activity in the area is done by individuals qualified or certified in the techniques of adhesive bonding. All work is accomplished with white gloves and with no contamination.

The adhesive is stored in a -20° F freezer until ready for use. As the material is removed from the freezer it is conditioned to room temperature before unsealing the container. This prevents moisture from accumulating on the adhesive.

Adhesive film rolls can be conveniently placed on a roll stand where the film can be rolled out on a cutting table and cut to the required size. When practical, the metal details to be bonded can be used as the cutting templates.

1. General Criteria for Layup Areas

   The requirements for layup areas of structural adhesive bonding shops engaged in repair of damaged aircraft assemblies should be as follows:

   - Limits of airborne particulate matter, temperature, and humidity shall be as specified in MIL-A-83377.

   - Airborne hydrocarbons shall be controlled by imposing operating restrictions. The number used for identification of each class shall correspond to the maximum number of particles, 0.5 micrometers or larger, permitted in one cubic foot of air.

   - Controlled environment areas for bonding do not fall within the definition of "clean rooms" according to FED-STD-209. The requirements for a "controlled area" room are recommended as minimums.

   - Noncritical areas do not fall within these definitions.

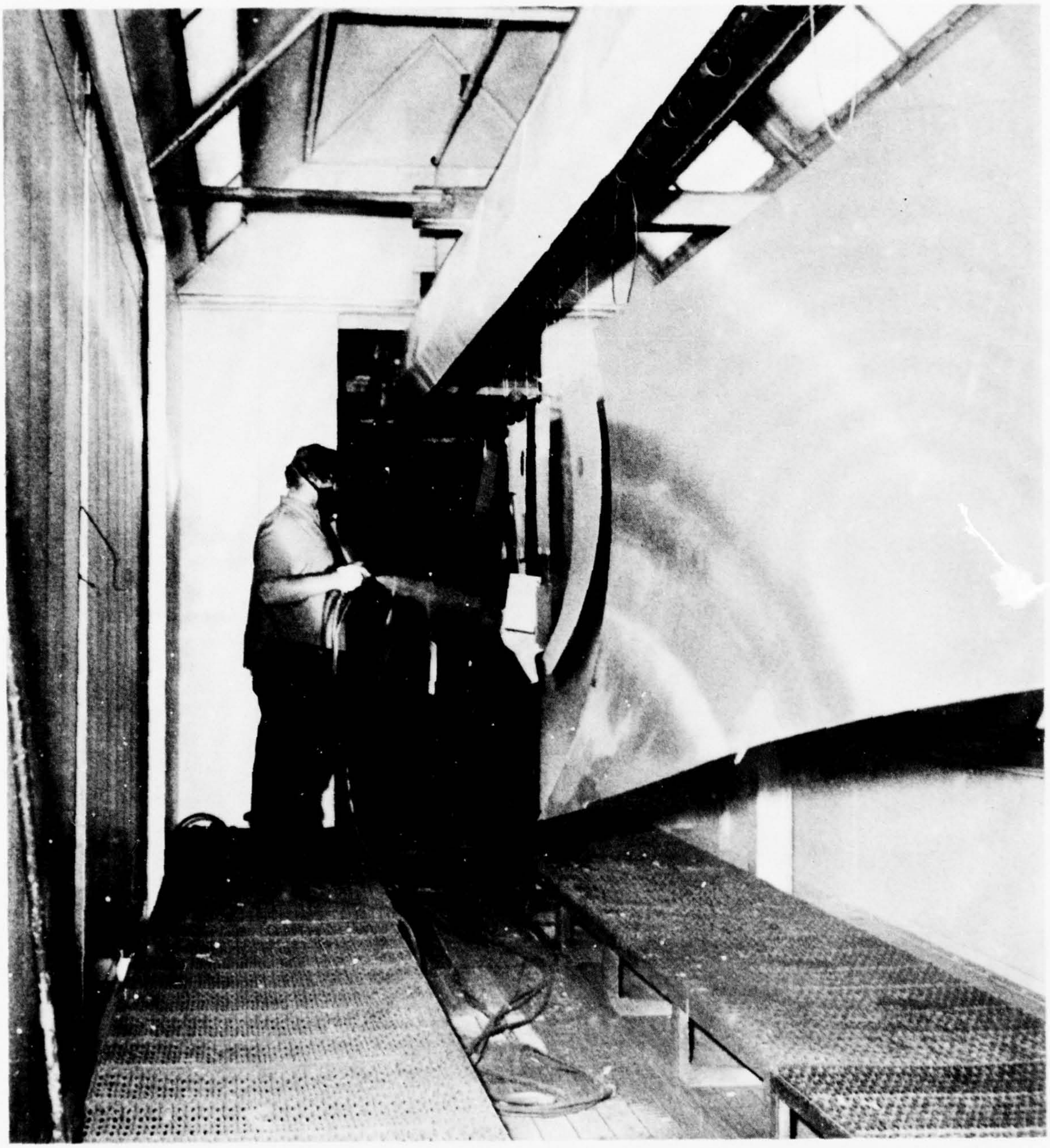


Figure 8-21.—Primer Application in Downdraft Spray Booth

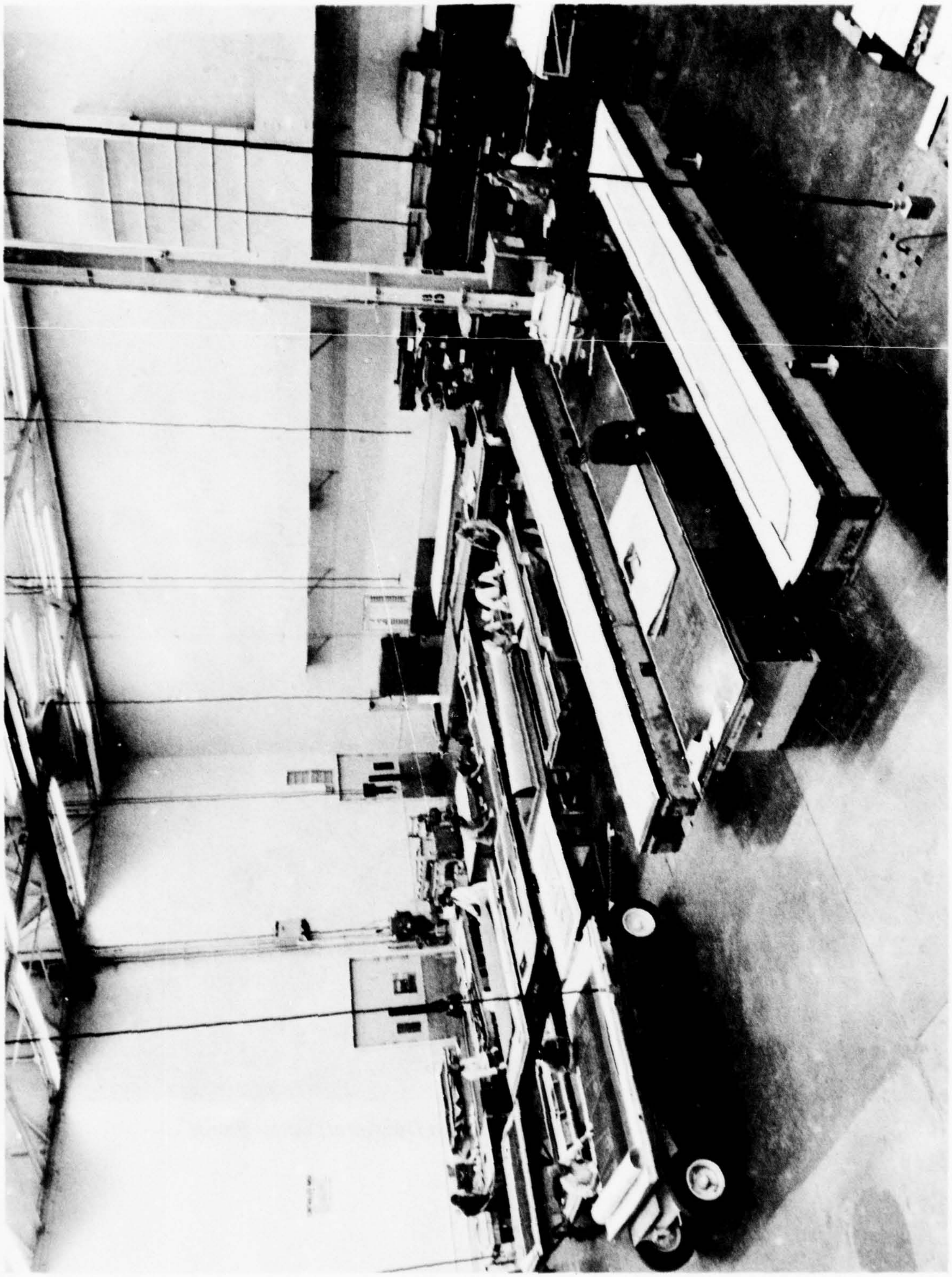


Figure 8-22.—Environmentally Controlled Adhesive Lay-Up Area

References:

FED-STD-201, Clean Room and Work Station Requirements, Controlled Environments.

T.O.-00-25-203, Contamination Control of Aerospace Facilities, U.S. Air Force.

ASTM F25, Methods of Sizing and Counting Air Borne Particulate Contamination in Clean Rooms and Other Dust Controlled Areas Designed for Electronic and Similar Applications.

ASTM F50, Method for Continuous Counting and Sizing of Airborne Particles in Dust Controlled Areas.

2. Controlled Areas

FED-STD-209 and T.O.-0025-203 should be used as a guide for the facilities construction.

The adhesive application area should be a separate, enclosed area. Special facilities should be provided to ensure that the application area is dust controlled. Filtered air should be constantly forced into the area to maintain the air pressure at a higher level than the surrounding area. This prevents contamination substances from entering the dust-controlled area when the doors to the surrounding areas are opened.

Unless otherwise noted, temperature and humidity should be monitored and shall meet the following requirements. Any method and equipment may be used for monitoring that gives assurance of maintaining proper control.

- Temperature 60° to 80° F
- Humidity 70% RH maximum

3. Equipment

- Tables or work benches used for the cutting, core splicing, etc., should be covered with a minimum of 1/2-inch-thick "Adyprene" polyurethane sheet.
- All other work tables should be covered with a suitable material to prevent damage to any component being bonded.
- No steam-heated or gas-operated vehicles or equipment shall be allowed in the controlled area.
- Smoking or eating shall not be permitted.
- Depackaging of materials, filing, drilling, cutting, or grinding of metals shall not be permitted in the controlled area.

- All materials, parts, tools, equipment, and other items to be used in this area shall be free of extraneous dirt, grease, oil, talc, or wax before entering the controlled area.

- All solvents used in this area shall be contained in safety cans or other containers meeting safety and hazardous-material-handling requirements.

- Electrically operated equipment may be allowed in the controlled area for short periods of time only.

4. Operating Conditions

- Restrict all unnecessary traffic.

- The list of personnel approved for access shall be screened.

- Cleanliness of parts entering the area shall be checked.

- Protective clothing requirements shall be met.

  NOTE: It has been determined that protective clothing must be worn for the purpose of limiting airborne particulate matter generation by personnel. The use of protective clothing also promotes a "controlled area psychology."

Additional guidelines are provided in T.O.-00-25-203.

5. Area Maintenance

- Areas should be constructed to be easily maintained.

- Areas should be partitioned to help prevent drafts from carrying contaminants in from the noncontrolled areas.

6. Personnel

- Personnel, including supervision and maintenance, that work in controlled environments covered by the above specification shall receive appropriate training in clean-room or controlled area procedures.

- The personnel working in these areas shall be certified in clean-room or controlled area procedures.

- Authorizing observers shall be familiarized with pertinent procedures and, when entering a clean room, be accompanied by a certified person. Their presence should also be restricted to aisle zones.

7. Responsibility for Inspection

- Unless otherwise designated, the quality control organization shall be responsible for the controlled area meeting and maintaining all the criteria required for high quality bonding operations.

- The amount or level of airborne particulate matter is determined by either the fallout, volumetric, or automatic particle counter method at the option of Quality Control.

8.4 CURING EQUIPMENT AND FACILITIES

8.4.1 AUTOCLAVES

The purpose of the autoclave is to provide a means of applying uniform high pressure and temperature to a part for cure. It has definite advantages over the use of other methods such as vacuum bags and heating blankets. The higher pressure provides a superior quality bond. The detail parts are better consolidated for intimate bondline contact.

Autoclaves should be operated by trained and certified operators whose task is to see that all safety procedures are followed throughout each cycle. Automatic recording and controlling equipment are available and should be used with each autoclave. The autoclave should be equipped with multiple thermocouple recording and/or controlling equipment so actual part temperatures can be monitored during cure.

Autoclaves are of various types and sizes. A larger size unit is shown in figure 8-23. Heat is provided by electricity, steam, or hot oil with air circulation. Pressurization is achieved by positive air pressure or inert gas. The assemblies to be pressurized are sealed under bagging film and either vented to the outside atmosphere or connected to a vacuum line. It is important that pressure not be directiy applied to honeycomb assemblies without the film barrier, as the pressure will laterally crush the core.

Conventional practice is to cover and seal the repair components after assembly for bonding. A vacuum is then pulled on the assembly to hold the details in position until the part is moved into the autoclave. Approximately 10 psi positive pressure is then applied by the autoclave before the vacuum lines are vented to atmosphere. Vacuum systems should be constructed so that they can be vented to atmosphere or connected to a gage system on the control console. The venting of vacuum outlet lines prevents a differential pressure from accumulating under the bag film. By monitoring the vacuum gages the operator has control of the go/no-go cure cycle for any assembly.

- Differential pressure from 0 to 6 inches Hg (0 to 3 psi) is allowed in the sealed area during a cure cycle.

- If the differential pressure rises above the 6-inch-Hg (3 psi) maximum and the temperature is 150° F or less, the cycle can be aborted and leaks or other malfunctions repaired before continuing the cure cycle.

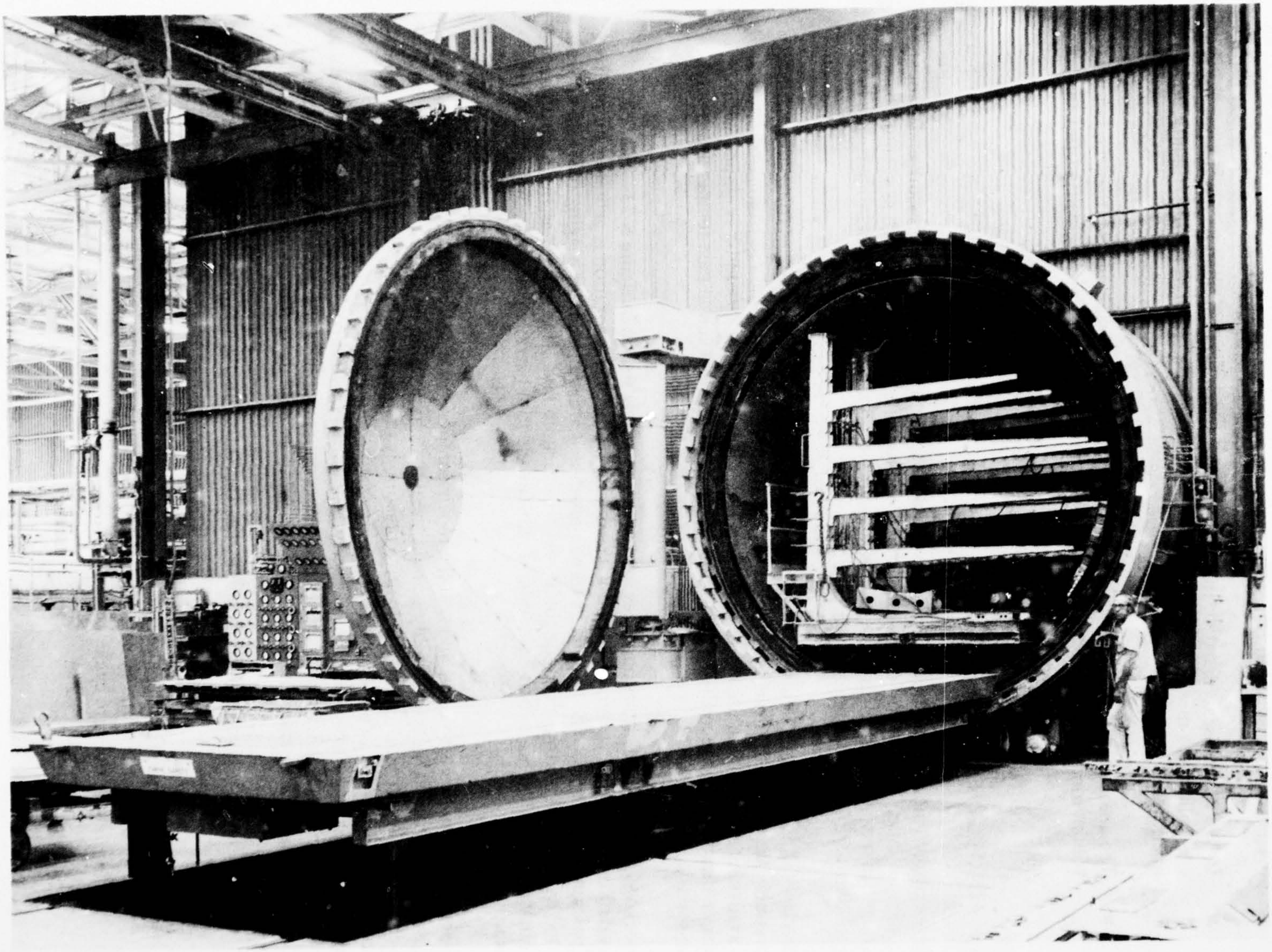


Figure 8-23.–Large Autoclave for Curing Bonded Assemblies

In some cases, combustible materials are used in the autoclave during cure. For example, wooden fairing bars may be used to keep the parts in position or to obtain proper pressure distribution. In these cases, the use of an inert gas in the autoclave is mandatory. The inert gas (CO_2 or N_2), when required, may be produced by an exothermic gas generator. The exhaust gases are typically transferred to a compressor system where the gases are compressed and stored in pressure vessels of adequate capability for the particular autoclave. Insert gas is also recommended for high temperature plastic laminating work (not covered in this document).

8.4.2 CURING OVENS

Curing ovens range in size from the small variety to larger walk-in types, as illustrated in figure 8-24. The larger ovens are typically gas heated with an air circulation system. Ovens should be equipped with a vacuum supply and multiple thermocouple connectors. These should be coupled with automatic controlling and recording equipment.

Ovens may be used for the initial cure when vacuum pressure is used. They may also be used for postcuring when the initial cure is accomplished in an autoclave under higher pressure.

8.5 HAND TOOLS AND MISCELLANEOUS EQUIPMENT

Tables 8-2 and 8-3 provide a listing of hand tools and miscellaneous equipment that are especially useful if performing repair operations on a bonded structure. In some cases, a source is given. This is for procurement convenience. It does not infer an endorsement of these particular suppliers. An alternate source may be used at the procurer's discretion.

Figure 8-24.—Large Walk-In-Type Curing Oven

Table 8-2.—Hand Tools

Tool	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Abrasive materials	Abrasive pad, nonwoven, nonmetallic MIL-A-9962A			
	Scotchbrite, type A very fine, maroon color	3M		
	Abrasive wheels, non-woven nylon, reinforced, type 3A MIL-W-81319A	3M		Use for abrading aluminum surfaces to remove organic surface finishes or light corrosion
	Abrasive cloth or paper, aluminum oxide, 120, 220, 320, 400, 500 grit, non-siliconized	Any source		
	Abrasive discs, 2 in., 3 in. dia., 220, 320, 400, 500 grit, non-siliconized, mechanical lock	Any source		
	Abrasive disk holder, SM3-T-4A (pad/stem) or equivalent	Standard Abrasive, Inc. 19015 Parthenic St. North Ridge, CA 91324		Use with sanding disk
	Emery cloth, fine grit	Any source		
Angles, 90° aluminum	Assorted sizes, shop stock	Commercial—any source		Use with clamp wedge blocks or repairs at edge of assemblies
Blade, saw	Razor 3/4 in., # 34-C	X-acto 4831 Van Dam St. Long Island City, N.J. 11101		Final sawing of extrusions and skins

Table 8-2.—(Continued)

Tool	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Blade handle, saw	X-acto # 5	X-acto 4831 Van Dam St. Long Island City, N.J. 11101		Handle for the # 34-C razor saw blade
Block, sanding	Metal or wood	Commercial—any source or in-house fabrication		Use with sanding paper to achieve a flat finish surface
Bottles, liquid dispensing, polyethylene	Squeeze-type, 16 oz, #16057-120 or equiv Use spout cap, 28 mm, #H-16657 or equiv	V.W.R. Scientific 600 So. Spokane St. Seattle, Wa. 98134		Dispensing cleaning solvents and liquids
Brush, acid		Commercial—any source	7920-00-225-8005	
Brush, paint	1.0 inch wide, short bristle	Commercial—any source		For application of solvents, paste, solvents, or adhesives
Burnishing tool	Metal, assorted sizes, spoon type	Commercial—any source	5120-239-8763	Use for burnishing scratches
Burnishing tool	0.187 polyethylene	Commercial—any source		Use for burnishing scratches
Cellophane	300 PT or 300 MD	Commercial—any source		
Chisel, wood	1/4 inch wide	Commercial—any source		Use to remove adhesive flash
Clamps, C-type	Assorted sizes	Commercial—any source		Use for mechanical clamping to apply pressure to a repair, or to wedge blocks (if used)
Containers, 1 liter beaker-type, polyethylene	# 13915-679 Sherwood or equiv	V.W.R. Scientific 600 So. Spokane St. Seattle, Wa. 98134		Mixing resins and potting compounds

Table 8-2.–(Continued)

Tool	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Containers, safety, foot-lever-type	Metal, Eagle 906-FL or equiv	V.W.R. Scientific 600 So. Spokane St. Seattle, Wa. 98134		Holding used clothes with toxic materials
Containers, cardboard	Nonwaxed, 16 oz liquid	Commercial–any source		Holding, carrying, or mixing wet or dry materials
Cork sheet	0.125-in.	Commercial–any source		Use to distribute pressure over area of a repair
Dividers, metal-marking	Capacity, 8 inches	Commercial-any source	5210-263-0376	Use for marking cutouts on aluminum or titanium surfaces and detail fabrication
Drills, hi-speed steel	Number or letter drill set, 90°/108° point angle	Commercial–any source		For drilling aluminum
Drills, cobalt	Number or letter drill set, 135° point angle	Commercial–any source		For drilling titanium
Drill stop, spring-loaded	Wedgelock DS-10 Wedgelock DS-20 Wedgelock DS-30 Wedgelock DS-40	Monogram Aerospace Fasteners 2343 So. Garfield Ave. Los Angeles, Ca. 90040		For setting drill depth
File, hand, flat mill	6-, 8-, 10-, or 12-in.	Commercial–any source		Use for deburring and sizing details
File, hand, round (rat-tail)	1/8-, 1/4-, 3/8-, or 1/2-in.	Commercial–any source		Use for deburring and filing holes
File, hand, rotary	1/2-, 3/4-, or 1-in. dia round end	Commercial–any source		Use for removing metal and honeycomb core
File, hand, flat vixon	12- or 14-in.	Commercial–any source		Use for heavy rough cut in metal removal

Table 8-2.—(Continued)

Tool	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Filter, polarized	Phosphoric acid anodize sorter	Wilco Co. 5519 6th Ave. So. Seattle, Wa. 98108		For examination of anodized surface for color change
Funnels, polyethylene, 28 mm opening, short stem	3-in. dia # 3-2050-040 6-in. dia # 3-2050-084 6-in. dia # 3-0255-088	V.W.R. Scientific 600 So. Spokane St. Seattle, Wa. 98134 or local supplier of laboratory supplies		Use for dispensing chemicals, solvents, or acids
Gloves, cotton	White, untreated, lintless	Cardinal Gloves Co. Newark, N.J.	8415-00-268-8353	Use for handling cleaned parts or adhesives
Gloves, insulating	Heat insulating	Any source		Use for handling hot parts
Gloves, rubber	Rubber or neoprene, surgeon's	Any source	8415-00-823-7456	Use to protect hands from acid, solvents, etc.
Hammer, machinists ball peen	Fed. GGG-H-86, type II, class 1, style A, 8 oz	Commercial—any source	5120-242-3913	Hand work
Hammer, tapping, inspection	(See fig. 10-7)	In-house fabrication		Inspection tool
Ink cartridges, marking	Marsh refillers or equiv	Marsh Co.		Use in marking pen
Knife, pocket	2 blade	Commercial—any source	5110-018-0999	Honeycomb core slicing, adhesive cutting, film cutting
Knife, putty	1-1/4-inches wide, FED. GGG-1C-00481	Commercial—any source	5120-294-4605	Core-slicing, compound-spreading, or making core removal or resin flash removal

Table 8-2.–(Continued)

Tool	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Knife, retractable blade	Mechanical, razor blade	Commercial–any source	Knife 5110-892-5071 Blades 5110-293-2865 Type I	Thin core slicing, adhesive cutting, film cutting, tape cutting, misc cutting or trimming
Mat, fiberglass	2 oz fiberglass or 7500 tooling mat	Ren Plastics 5656 S. Cedar Lansing, Mich Hysol, (Div. of Dexter Corp) 15051 E. Don Julian Rd. Industry, Calif. 91744		Can be used for laminated tooling, fiberglass bleeder cloth, insulation material, or a substitute for Osnaburg bleeder cloth
Micrometers, gap-type, certified	0.0 to 1.0 inch, adjustable stem	Commercial–any source	5210-243-2935	Use for thickness measurements of sheet metal and for inspection operations
Micrometers, depth, certified	0.0 to 2.0 inches	Commercial–any source		Use for measuring depth of honeycomb core or assembly thickness
Needle, hypodermic	18 gage, 2 inches long, # BD-1098 *Becton/Dickson*	V.W.R. Scientific 600 So. Spokane St. Seattle, Wa. 98134		Cut stem to length desired. Use for resin injections to fill voids
Pressure plates	0.125 and 0.250 aluminum plate, various sizes 6061-T4 alum alloy plate or equiv	Commercial–any source		Use for pressure application during the cure cycle
Pen, marking	Refillable, felt-tip	Esterbrook Pen Co.		Marking of damage outlines and identification of details
Phenolic sheet	0.125 template stock MIL-P-15035 *or equiv*	Commercial–any source		Use for router templates

Table 8-2.—(Continued)

Tool	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Pipet, straight tip medicine dropper	#52950-002 or equiv	V.W.R. Scientific 600 So. Spokane St. Seattle, Wa. 98134		Use for injection of liquid adhesive
Plastic sheet, acrylic	0.187 drill template stock or equiv MIL-P-5425A	Commercial—any source		Use for drill templates
Plastic sheet, mylar	0.0075 in. wide, 650-ft roll	DuPont		Use for making outline templates for honeycomb core details
Plastic applicator	P.A-1 plastic	3M		Use for spreading, screeding, and smoothing of adhesives, resins, or compounds
Plate, mixing	0.125 or 0.250 aluminum plate	Commercial—any source, in-house shop stock		Mylar sheet can be used as a substitute for mixing compounds, resins, or adhesive pastes
Pliers, angle nose, multiple hole	Fed. GGG-P-00471, type II, style B, class 1	Commercial—any source	5120-540-2464	Manual use
Pliers, duckbill, 6-inch	Fed. GGG-P-471	Commercial—any source	5120-256-2150	Manual use
Pliers, needle nose straight	Fed. GGG-P-471	Commercial—any source	5120-926-7196	Manual use
Pliers, straight nose slip-joint w/cutter	Fed. GGG-P-471	Commercial—any source	5120-223-7396	Manual use
Plywood, indoor	0.250 template stock or equiv	Commercial—any source		Use for router templates
Rod, stirring	0.125-through 0.375-in. dia steel, glass, or polyethylene	Commercial—any source		Use for mixing or stirring liquids and compounds

Table 8-2.—(Continued)

Tool	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Roller	Wood or hard rubber, 6 inches long, 2-in. dia	Commercial—any source		Roll out compounds, liquid adhesives, or trapped air under films or cloth
Router attachment	Model QRC-3C or QRC-3D Collet, 9003 Nose, 9013, 9022 Bearing, 9015 Ret. ring, 9016; #881390 complete, use with model 11GLF-230/250 router motors	Tool Group, Dresser Industries 6114 6th Ave. So. Seattle, Washington 98108		Hand-routing of damaged material with router bit guide *that includes set-back* dimensional
Router bushing	#SP-310-31J or equivalent	Sheridan Products, Inc. 1054 E. Hyde Park Blvd. Inglewood, Cal. 90302		Use with QRC-3C and -3D router motors
Router, motor	Pneumatic, hi-speed, 20,000 rpm, QRC-3C or 3D or equivalent	Tool Group, Dresser Industries 6114 6th Ave. S. Seattle, Washington 98108		Use for damage removal; *see* "Router Attachment" for QRC Routers
	Pneumatic, hi-speed, model 11GLF-230 rpm 25,000, with accessories	Tool Group Dresser Industries 6114 6th Ave. So. Seattle, Washington 98108		Use #881390 router attachment; includes setback bushing
Router bits	1/4-in. dia, 2-flute LH spiral, hi-speed steel *for aluminum;* 1/4-in. dia, 3-flute LH spiral, carbide for titanium	Commercial—any source		Use with any router motor
Safety face shield	Tru-safe #119-1 or Safeline #6799 (10 by 18-1/4) or equiv	Commercial—any source		For face and eye protection

Table 8-2.—(Continued)

Tool	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Safety face shield holder	Rice head shield # 707 or equiv	Commercial—any source		Holds replaceable face shield
Safety glasses	5944D smoke clear lenses	H. L. Bouton Co. Inc. Buzzard Bay, Mass. 02532		For eye protection
Saw, circular with adapter and blade	CP-3017-OKS-1000-3 or equivalent	Chicago Pneumatic Tool Co. 6 East 44th St. New York, N.Y. 10017		Use to saw slots in panel skins for strip removal
Saw, reciprocating with blades	For aluminum ot Ti skins, CP-3017-F0 or equivalent	Chicago Pneumatic Tool Co. 6 East 44th Street New York, N.Y. 10017		Use to remove damaged material from bonded panels
Saw, slotting	1/4-in. dia arbor hole, 2-in. blade	Commercial—any source		Use for removal of damaged material
Saw, arbor	1/4-in. dia expandable end, allen screw lock	In-house fabrication (see fig. 8-12)		Holding arbor for slotting saw blades
Saw, cutter	5/8 inch			Cutter for arbor saw
Saw, hole	1/2-, 1-, 2-, 3-, and 4-in. dia	Commercial—any source		Use for removal of damaged material
Saw blade holder		Commercial—any source		Holder for hacksaw blades
Saw, blade	Hack saw, 12-inch, assorted teeth, 18, 24, 28, and 32 per inch	Commercial—any source		Use for removal or damaged material
Scale, flexible	6-in. # 2105R tempered or equiv	Lufkin Rule Co. Saginaw, Mich.		Determining sizes

Table 8-2.–(Concluded)

Tool	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Scale, flexible	12-in. # 338R tempered or equiv	L.S. Starrett Co. Athol, Mass.		Determining sizes
Scissors	6- or 8-inch cutting blade	Commercial–any source	5110-223-6370	Cutting films, cloth, adhesives, etc.
Screen wire	# 16 mesh 0.018 dia. wire CRS type 304	Pacific Wire Works, Inc. 2743 13th S.W. Seattle, WA. 98124		Use for phosphoric acid anodizing
Scribe	Reversible point	Commercial–any source		Making detail layout outlines on mylar or template stock
Shears, metal cutting	10-in. Fed. GGG-5-291 type II, class 1, style B	Commercial–any source	5110-654-7425	Cutting metal details, prefit trimming of details
Sponge, cellulose		Commercial–any source		Use with chemicals and acids
Spatula, mixing	Wood or metal	Commercial–any source		Mixing compounds, slicing light density core, spreading compounds and adhesives
Square, combination	12-in. grooved blade, style 'BP'	Commercial–any source	5210-078-8949	Marking details
Squeege, flat	Synthetic rubber, phenolic laminate, or plexiglass	Commercial–any source		Use for smoothing resins or compounds
Tongue depressors	Wood	Commercial–any source		Mixing and spreading compounds and adhesives
Wire, thermocouple	Iron-constantine, type J, or equiv	Commercial–any source		For recording temperature of cure cycle
Wrench, open end adjustable	MIL-W-17912 type I	Commercial–any source	5120-278-0341	Installation and removal of nuts and bolts

Table 8-3.—Miscellaneous Equipment

Item	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Air-blast gun	Vacu-Blast Jr., #41303 or equivalent	Vacu-Blast Company Balmont, Cal.		Clean metal surfaces
Aspirator, vacuum	Vacuum model TD-260 or equivalent	Airvac Engineering Milford, Conn.		Converts air pressure to vacuum
Bags, pressure	10-lb sand or shot bags	Commercial — any source		Use as a substitute pressure medium
Blanket, heating, silicone rubber and fiberglass cloth	115 volt, 60 cycle, 10 W/in^2, made to order	Briscoe Mfg. Co. 1055 Gibbard Ave. P.O. Box 628-R Columbus, Ohio 43216		To provide heat for curing adhesive
		Rama Industrial Heater Co. 39651 Esplanade San Jacinto, Cal. 92383		
		American Thermo Products Los Angeles, Cal.		
		Electro Film, Inc. No. Hollywood, Cal.		
	With a vacuum seal, order #AS-VHB-1083 series; without vacuum seal, order #AS-VHB-1000 series	Airline Systems, Div. of Adhesive Engineering Co. San Carlos, Cal.		

Table 8-3.–(Continued)

Item	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Cleaner, vacuum	Industrial-type model #APN4423 (Tornado); use a 556AL barrel as a dust receiver	Breuer Electric Mfg. Co. Chicago, Ill.		Clean up sanding dust and debris
Countersink, microstop, 100° adjustable drive	#6300–large, #6400–small, or equivalent	Schrillo Los Angeles, Cal.		Countersinking holes for rivets, screws, or bolts
Cutter kit, honeycomb-slicer-type (toothless circular saw)	Purchase 3-in. dia	Commercial – any source		The cutter diameter decreases due to sharpening
Drill motor	Electric 600 rpm, model 15C 1489 or equivalent	Dotco, Inc. Ohio Route 18, East Hicksville, Ohio	5130-889-1840	Conventional drilling, sanding, or circular sawing
	Pneumatic, 1/4-in. chuck, model #3008-0 or equivalent	Chicago Pneumatic Tool Company 6 East 44th Street New York, N.Y. 10017		
Drill motor, 90° Angle	Pneumatic, variable speed, model #10L-1201B or equivalent	Dotco, Inc. Ohio Route 18 East Hicksville, Ohio		Conventional drilling, sanding, or circular sawing
Gauge, air pressure	0 to 100 psi, model J4654 or equivalent	Marsh Instrument Co. Skokie, Ill.		To indicate air line pressure
Gauge, vacuum	0 to 32 in. Hg	Marsh Instrument Co. Skokie, Ill.		To indicate vacuum line pressure

Table 8-3.–(Continued)

Item	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Heater assembly	Hot air, BF-400-10, or equivalent MIL-H-4607	Hermon-Nelson Div. American Eilter Co. Moline, Ill.		Hot air blower to duct air to area being cured
Heater, air	1000 to 2000 watts, model HGs 50110J	Master Appliance Corp. Racine, Wisconsin		For heat-tacking adhesives, heat-drying honeycomb core or assemblies, warming compounds and/or resins
	Alternate	Ideal Industries, Inc. 1006 Park Avenue Sycamore, Ill 60178		
Lamp, heating	250 to 300 watts, explosionproof, Tungsten or quartz tube	Westinghouse Electric Corp 1180 Andover Park, West Tukwila, Wa. 98198		Low-temperature curing of adhesives, potting compounds, or resins
Lamp, heating assembly	25 or 40/4 #375G30 or equivalent	Deltrol Controls Corp. 2745 So. 19th Street Milwaukee, Wisconsin 53215		Low-temperature curing of adhesives, potting compounds, or resins
Motor assembly, *pneumatic*	Arbor saw/motor	Dotco, Inc. Ohio Route 18, East Hicksville, Ohio		To cut away damaged material
Multitester	Low current, low OHM, Kelvin-bridge-type	Commercial – any source		Taking electronic measurements
Peening tool, power	1/4-in. stem (drill rod), slot end for flapper strip MIL-B-1170, type II, class E, style 1	Van Pak Products, Inc. #1312 (flapper strips only)		Makes use of peening technique to shape small sheet metal details to contour; use with Dotco air motor
Power supply, dc	Regal Line model R2518 un-filtered bench model R series dc	Oxy Metal Industries 6404 N.E. Halsey Portland, Or. 97213		Use as power source for phosphoric acid anodizing

Table 8-3.–(Continued)

Item	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
Pyrometer, temperature control	0^{o} to 400^{o} F, model 70323 or equivalent	Thermo Electric Co. Inc. Saddle Rock, N.J.		Use as temperature indicator during cure cycle
Recorder, temperature, 24-point, automatic chart-type	Model #Y15305836-24	Honeywell Philadelphia, Pa.		Measuring temperature at the adhesive cure line by thermo-couples; 1 through 24 points available
Recorder, temperature, 1-point, individual printout, roller chart	Model #122 115 volt, 60 cycle	Rustrok Instrument Co., Inc. Manchester, N.H.		Measuring one thermocouple on a line chart
Regulator, air pressure	0 to 125 psi, model 11-002-025 or equivalent	C.A. Norgren Co. Littleton, Colorado		Measure and regulate air pressure
Regulator, vacuum	0 to 30 inch. Hg, model H-20WT-0-15 or equivalent	Conoflcw Corp. Blackwood, N.J. 08012		Measuring vacuum at the assembly

Table 8-3.–(Concluded)

[illegible]	Manufacturer's designation	Manufacturer	Federal stock no.	Remarks
[illegible]	#1-996, 1.0 gram accuracy, or equivalent	Shakeproof Div. Illinois Tool Works, Inc. St. Charles Road Elgin, Ill.		Weighing compounds and resin mixtures
[illegible]	Air-operated, model 507 or equivalent	Semco Sales & Service Inc. 1313 Florence Avenue Inglewood, Cal.	5120-924-2872	Dispensing of fillers and sealants
[illegible]	Model 2T-405, adjustable, or equivalent	Zepher Mfg. Co. Hindry & Redondo Blvd. Ingelwood, Cal.		Shave protruding rivet heads
[illegible]	0° to 45° inclination from horizontal position	Brown & Sharpe		Use with core-slicing equipment
[illegible]	Power unit, atomized w/glass 6 oz container	Preval Sprayer Division *Precision Valve Corp.* P.O. Box 309 Yonkers, N.Y. 10702		Used to apply small amounts of liquid primer, adhesive, or resins
[illegible]	AS-TCC-2003, complete/ except no connector cables; AS-TCC-6000, power cable AS-TCC-7000, T/C cable	Airline Systems, Adhesive Engineering Co. 1411 Industrial San Carlos, Cal. 94070		Use with heat blankets of other makes or as a complete package including temperature recording and pressure
[illegible]	Variable control 115 volt, 60 cycle, "Variac" model 1701AK or equivalent	General Radio Company 13361 Armstrong Avenue Santa Ana, Cal.		Use with heating blankets as a power supply
[illegible]	Vacu-Valve, #401 round base, #401A rectangular base	Airtech International, Inc. P.O. Box 3387 25512 East Baseline San Bernadino, Cal. 92404		Use for evacuation of air inside bag film

9.0 TOOL FABRICATION

The bonding tool basically performs two functions for the bonding operation. First, it maintains or determines the part contour. Secondly, it provides a base for fixing the details in place so they do not shift during the curing process.

Three types of tools are most commonly used for repair. In the simpler case, the tool may provide a rigid flat surface. Pin points may be provided to fix the details. An illustration of this type of tool is shown in figure 9-1.

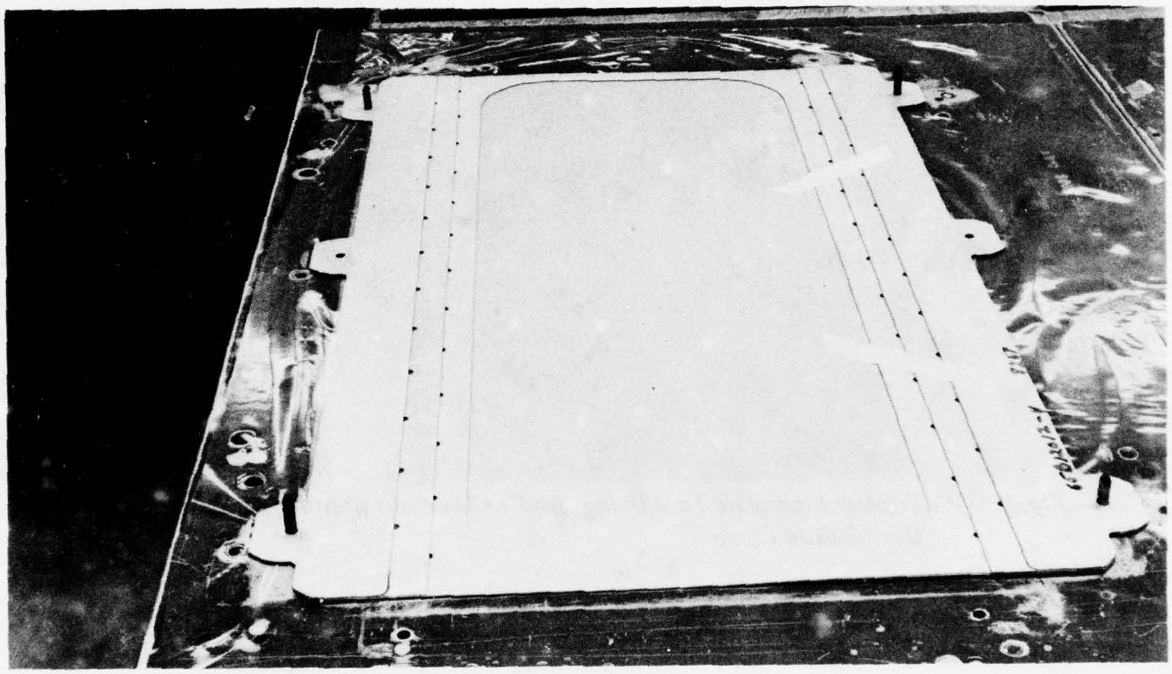


Figure 9-1.—Flat Platen Tool With Skin Location Fixed With Pins

A second case is when the surface of the part is contoured. If the repair is not too extensive, a simple tool may be required only in the repair area. An example of such a tool made of fiberglass is shown in figure 9-2. This type of tool is quick to fabricate and relatively inexpensive. Note that it does not provide support for the entire component. Instructions for fabricating tools of this type are given in section 9.3.

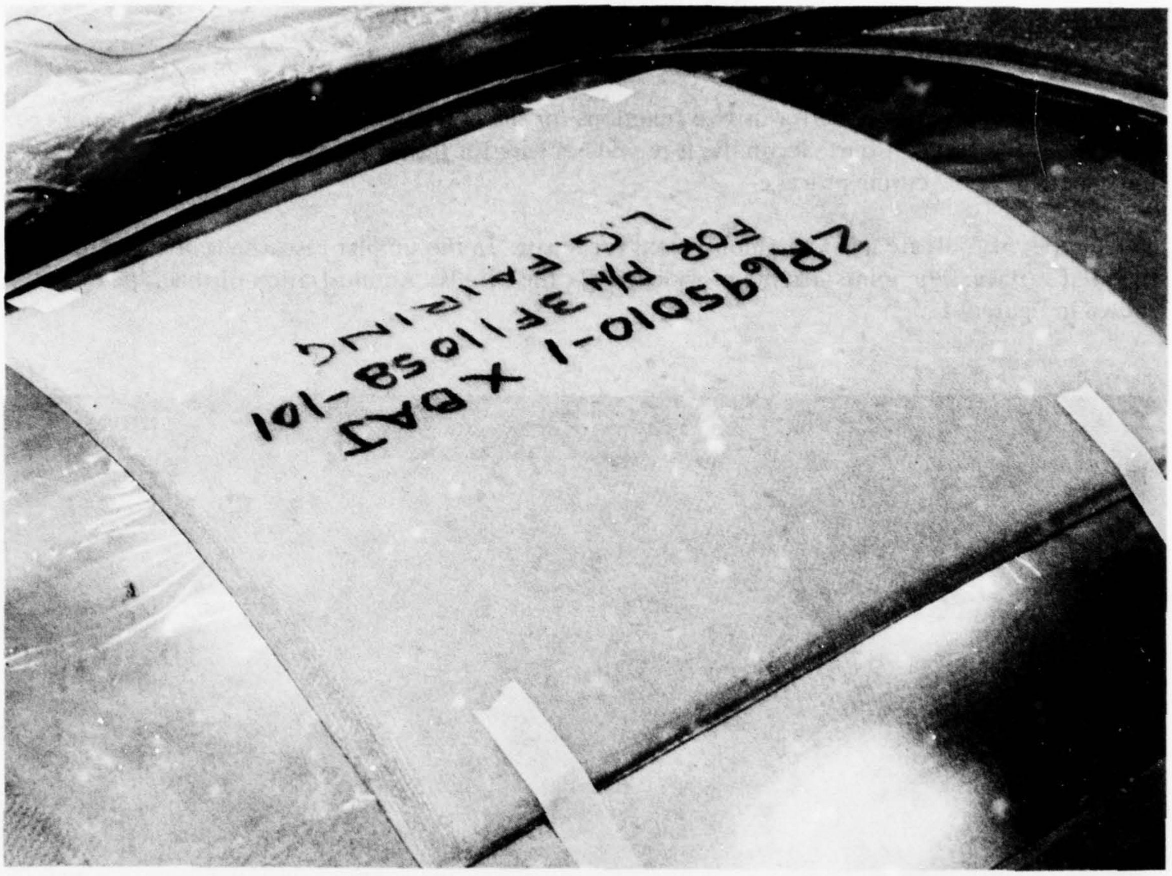


Figure 9-2.—Typical Fiberglass Tool Being Used to Maintain Contour of Repair Details During Cure Cycle

More substantial tooling is commonly required where the repair is quite extensive or the part is being rebuilt. In such a case, the tool surface usually determines the final part shape. A tool of this type used for rebuilding a wing leading-edge section is shown in figure 9-3. During the cure, the assembly is fully supported in the bonding tool. Caul plates and fairing bars are used to distribute the pressure and provide fixity during the bond. As a result, the cure may be made at the original cure temperature. The design of this type of tool is discussed in sections 9.2 and 9.3.

Care must be taken in the design to ensure that the tool is sufficiently rigid to maintain the desired part contour. As the pressure is applied, the assembly details must comply to the tool contour and not vice versa. Much of this is accomplished while fabricating the part details themselves. Thin, single-contoured skins and doublers may form easily to the tool surface. Thicker skins, doublers, and core for other than very large radii will require preforming. Compound-contoured skins and core and heavy sections will require forming or machining to close tolerances.

The tool designer must consider thermal conductivity of the tool and the ability to get heat to the part. Face thicknesses of fiberglass tools should, in general, be limited to 0.25 inch. Additional rigidity, if required, should be obtained by adding stiffeners. These should be designed to allow free hot air flow.

A different problem involving heat flow may be encountered in the use of metal tools. If the repair is heated with blankets, the tool may conduct heat away from the repair and not allow the required temperature rise rate or the maximum temperature to be reached. This may usually be remedied by extending the area of the heating blankets. In other cases it may be necessary to reduce the tool

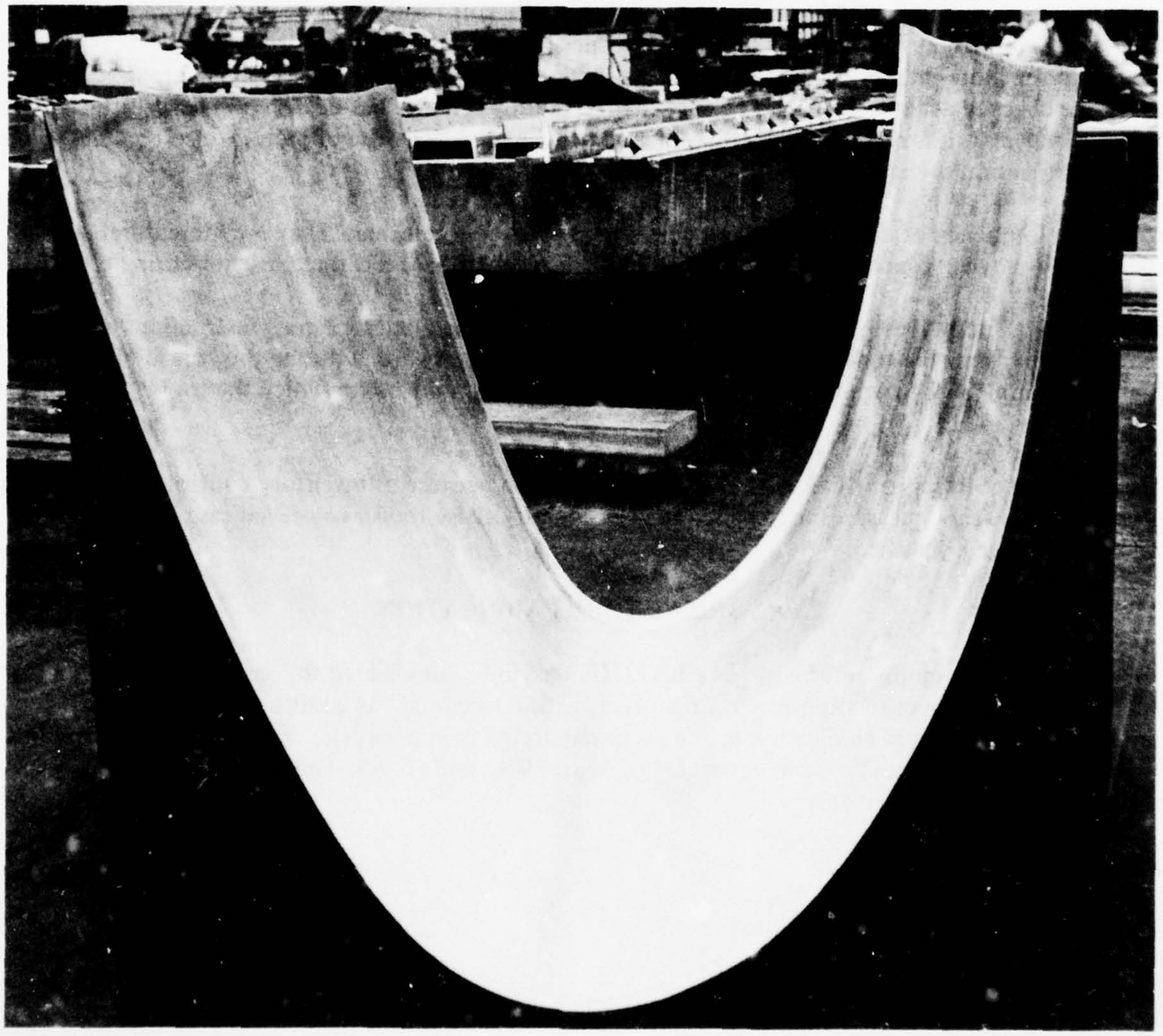


Figure 9-3.—Metal Bonding Tool Used for Rebuilding Wing Leading-Edge Section

mass. Selecting an adhesive that has wide tolerance to heat-up rate might also offer a solution. Adequate thermocouples should be used to ensure that specifications for the cure are met.

Differential thermal expansion between the tool and the aluminum-bonded part should not be a problem if aluminum or fiberglass tools are used. STEEL TOOLS SHOULD NOT BE USED FOR BONDING ALUMINUM PARTS. Steel may be used in most cases for bonding titanium.

9.1 METAL VERSUS FIBERGLASS TOOLS

The trade-off between fiberglass (soft) tools and metal (hard) tools is largely a consideration of cost and tool size. The fiberglass tool is relatively inexpensive and may serve adequately if the repair is small or of moderate size. It can be made quite quickly by molding it to the surface of an undamaged part or to the surface of a damaged part that has been temporarily cosmetically treated. In the former case, the parts must be interchangeable. The problem with soft tools is that they are more easily damaged than the metal tools and will warp with successive use. As a general rule, if the tool is to be used to repair more than four parts, it should be supplementally stiffened to prevent warpage. It should be checked after each cure to be sure that no contour change has occurred. If over fifteen parts are to be repaired, it is recommended that a metal tool be used. The use of metal is also recommended for the fabrication of very large tools.

Where the frequency of use justifies their cost, metal tools are preferred. They are more durable and rigid. They provide a superior base for attaching such accessories as locating pins and fairing bars.

Consideration should be given to obtaining metal tools from the manufacturer. Instructions should be included on how the tools were used. Tools are commonly reworked during the course of production to accommodate part modifications. The airplane serial numbers for which the tool is applicable should be specified.

The retention of infrequently used tools may be a problem because of inventory control considerations. In these cases, measures may be required to identify these tools as a special case in which extended storage is justified.

9.2 METAL TOOL FABRICATION

The metal tool commonly referred to as a BAJ (bond assembly jig) is used to locate detail parts and/or subassemblies in correct relationship to each other, within tolerance. It additionally provides or permits uniform pressure application to the assembly during the cure cycle. Typical BAJ's for use in air- or platen-heated autoclaves are illustrated in figures 9-4 through 9-7. General considerations regarding BAJ design are as follows:

Material

Aluminum, 6061, weldable, unpainted

Tolerance

One-third of the production tolerance, unless otherwise specified

Finish

125 rms on surfaces contacting the part or assembly to be bonded

General Design Criteria

1. The BAJ must provide uniform heat transfer, bond line pressure, and configuration control.

2. The platen heat autoclave transfers heat by conduction from the platen surface through the BAJ base to the curing assembly.

3. The air heat autoclave transfers heat by convection to the BAJ and the curing assembly.

4. Convection heated BAJ's should be designed to provide maximum air movement through the tool support structure and to the surfaces that transfer the heat to the curing assembly.

5. Design the BAJ to rest the assembly on the aerodynamic or appearance critical surface.

6. BAJ's are constructed from materials which resist distortion due to the thermal cycling, and have a thermal coefficient of expansion similar to that of the material being bonded.

7. Tool materials must be free of porosity and of a quality sufficient to ensure vacuum integrity during the entire bond cycle.

8. Working holes in aluminum tool details should have steel bushings.

9. Scribed lines, in the excess area around the assembly, may be called out on the BAJ tool drawing for locating edges of the part details.

10. For alignment purposes, sight holes will be required through tooling details that obscure the alignment view.

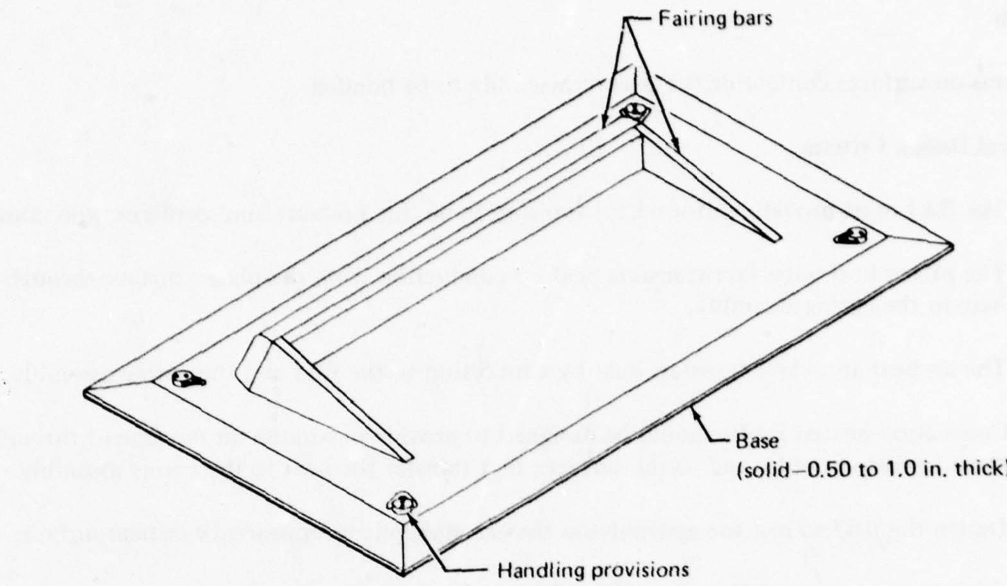
Removable Tool Components

1. Removable tool components are positioned with locating pins. Vacuum blanket pressure applied to these components usually provides sufficient clamping.

2. Provide interchangeability between identical loose details and in hole patterns in details performing operations on the BAJ wherever practical.

3. Minimize the use of screws and bolts that require removal or adjustment during BAJ usage.

4. The weight of individual removable components should not exceed 25 pounds for ease of handling. Fairing bar lengths should be a function of weight and strength. Long lightweight bars should be divided into practical lengths for handling.



Note: This type of BAJ is used to accommodate assemblies that are flat or with slight contour. These BAJ's are machined from plate stock of sufficient thickness to ensure stability.

Figure 9-4.–Typical BAJ for Platen-Heated Autoclave

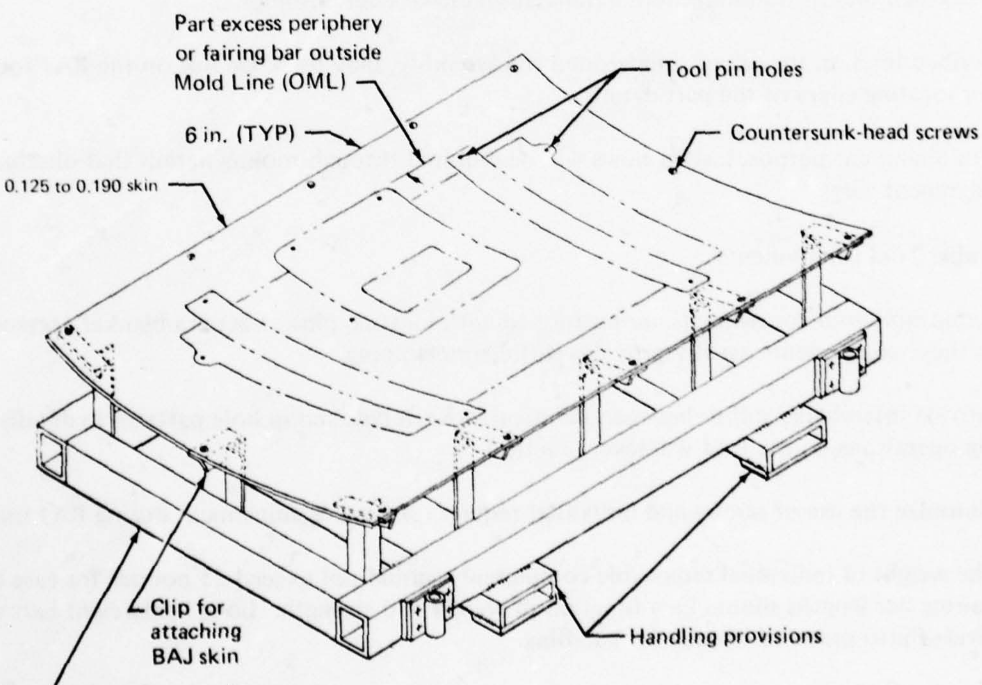


Figure 9-5.–Typical BAJ for Air-Heated Autoclave Using Skin Preformed to Contour

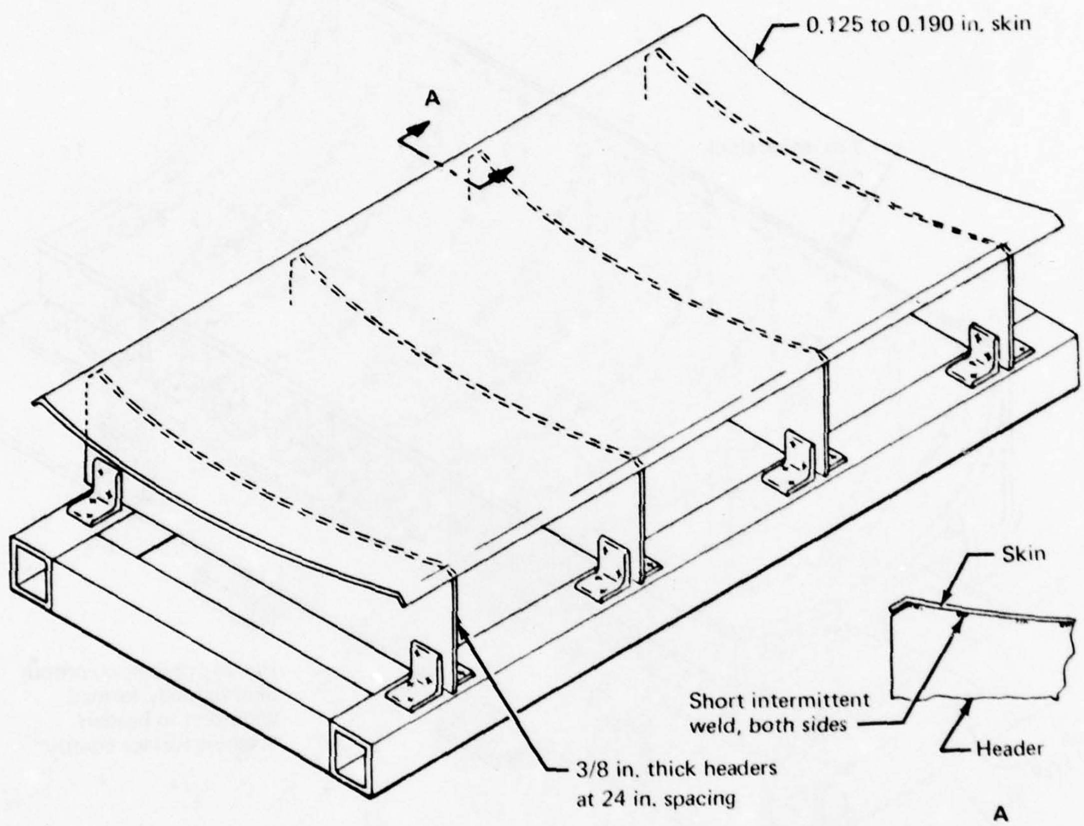


Figure 9-6.—Typical BAJ for Air-Heated Autoclave Using Skin Preformed to Contour

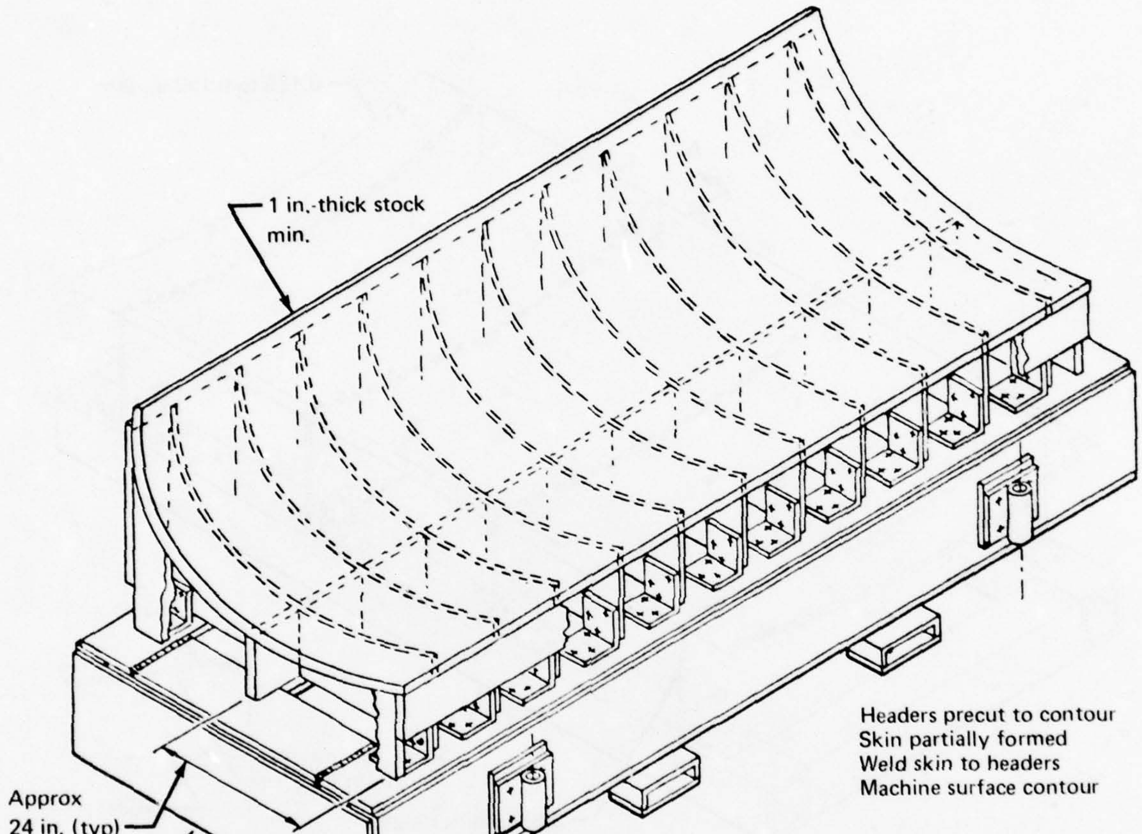


Figure 9-7.—Typical BAJ for Air-Heated Autoclave for Compound or Complex Contour

9.2.1 FAIRING BARS

Fairing bars, removable from the BAJ, provide a smooth transition for the vacuum blanket from the bond assembly surface to the base of the BAJ. A typical fairing bar application is illustrated in figures 9-8 and 9-9.

The bar must be higher than the total height of the bond assembly to:

- Assure consistent pressure on the periphery of the bond assembly to reduce the chance of crushing the core
- Contain the upper skin which, in most cases, is located by the fairing bar in order to reduce the chance for the skin to slip up on the fairing bar

Fairing bars on severe contour BAJ's may require fabricated construction. Consider fiberglass and resin laminate, molded urethane for up to 250° F service, and aluminum for service above 250° F.

NOTE: Fairing bars and other tool details may be coated with a teflon coating or wrapped in release film to prevent the adhesive from bonding to their surface.

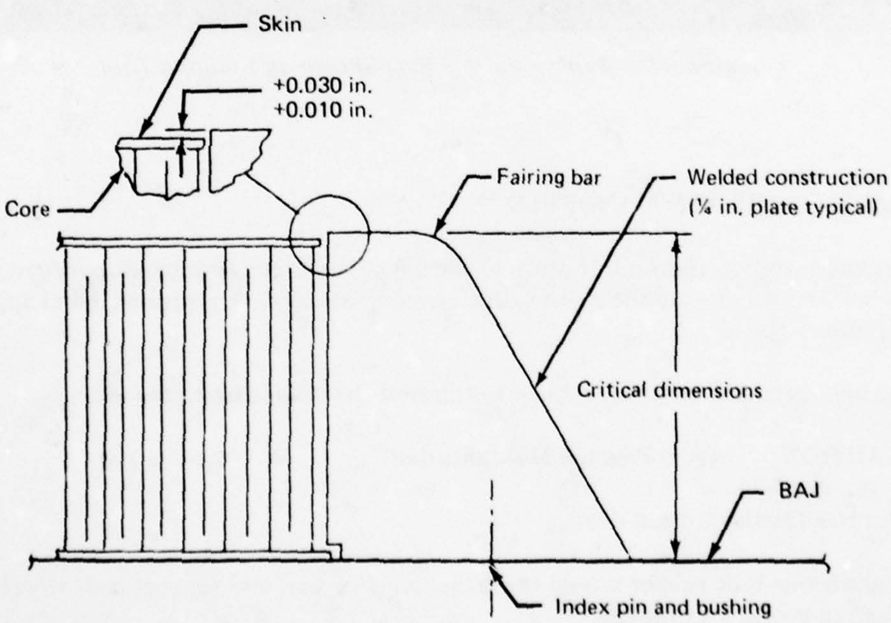


Figure 9-8.—Typical Fairing Bar Application

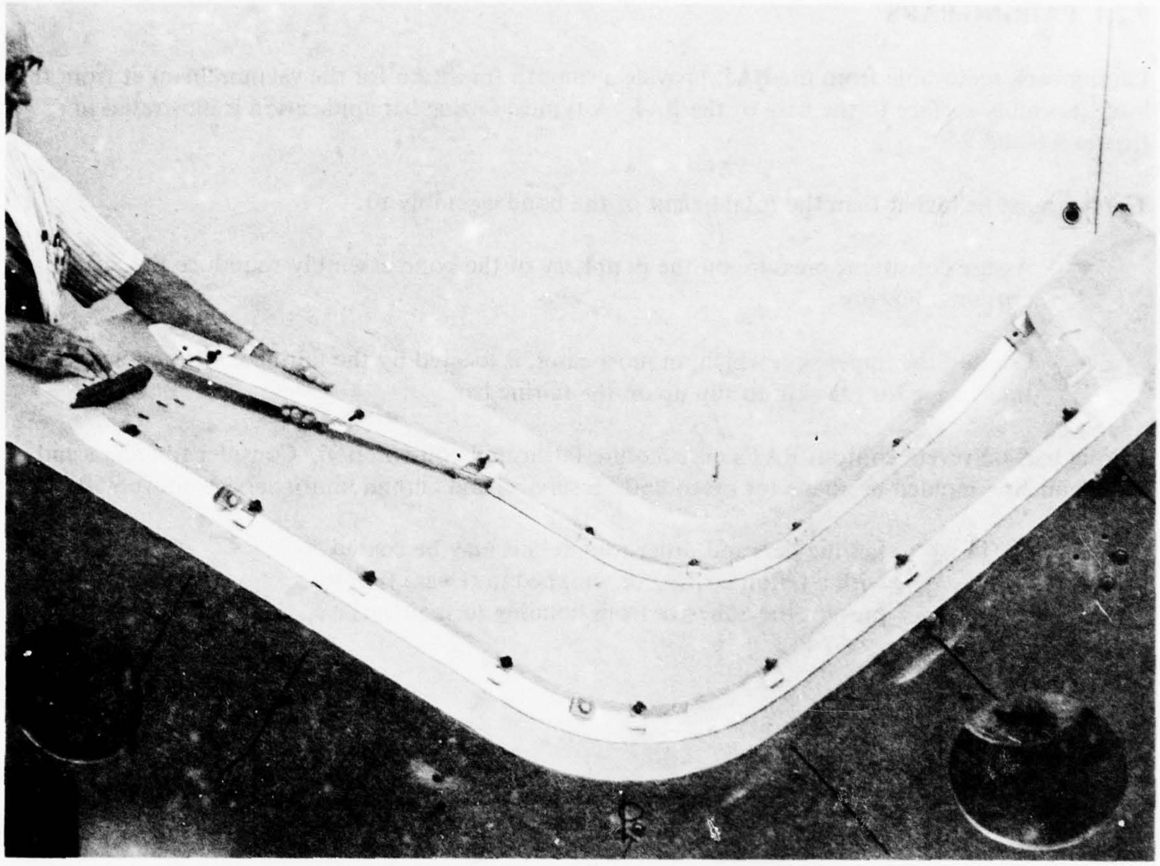


Figure 9-9.—Typical Fairing Bars Shown on Bonding Tool

9.2.2 PRESSURE BARS AND MANDRELS

Pressure bars and mandrels transmit pressure to the lower bond line, and may support an upper flange bond line and may locate the spar or edge member laterally. A typical mandrel application is shown in figure 9-10.

Pressure bars and mandrels must be designed to transmit the desired unit pressure.

CAUTION: Avoid Pressure Multiplication!!

They must be free floating up and down.

Heat-resisting silicone-type rubber is used for facing pressure bars and support pads where interface tolerance buildup presents a problem.

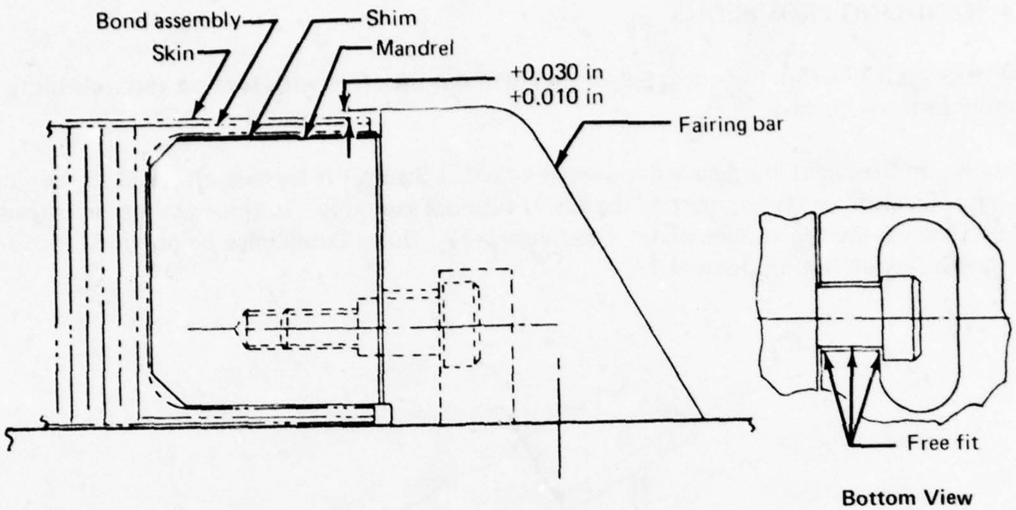


Figure 9-10.—Typical Pressure Mandrel Application

9.2.3 VACUUM BLANKET SUPPORT DETAILS

Fairing and shroud details must be provided to support the vacuum blanket. Typical use of these is illustrated in figure 9-11. Locate these details next to mandrels, along with fairing bars, and in corners or openings in bond assemblies.

Consider the total pressures involved over the entire area when selecting material thickness and gusset requirements.

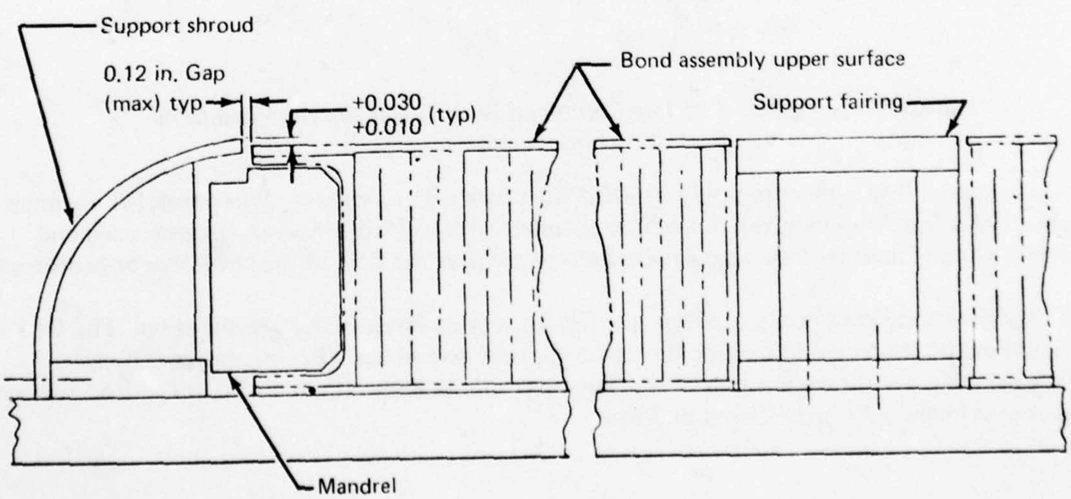


Figure 9-11.—Typical Vacuum Blanket Support Details

9.2.4 HANDLING PROVISIONS

Hoist rings on BAJ's should be located so they will not interfere with loading and unloading the bond assembly in the autoclave.

Generally, on the larger and heavier convection-heated BAJ's, lift lugs are attached to the sides of the BAJ base structure or made a part of the caster support assembly. In this way, any overhead lifting will not damage the top surface plate. See figure 9-12. Holes should also be provided for fork lifts as is shown for the tool in figure 9-13.

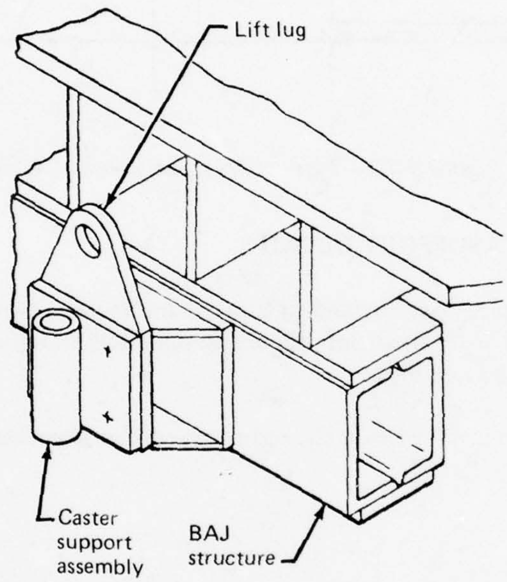


Figure 9-12.—Typical Lift Lug Combined With Caster Support Assembly

Convection-heated BAJ's are commonly handled with fork lift equipment. When fork lift channels are included in the BAJ design, call out 8-inch channels with welded keeper-straps near each end. Locate fork lift channels to clear finger racks used to support the BAJ in the autoclave or in storage.

Removable casters are commonly used for moving convection-heated BAJ's in the shop. The BAJ design and construction should include the caster support assemblies. Typical caster and caster support assemblies are shown in figure 9-14. Supports should be positioned so that the BAJ surface plate is approximately 31 inches from the floor.

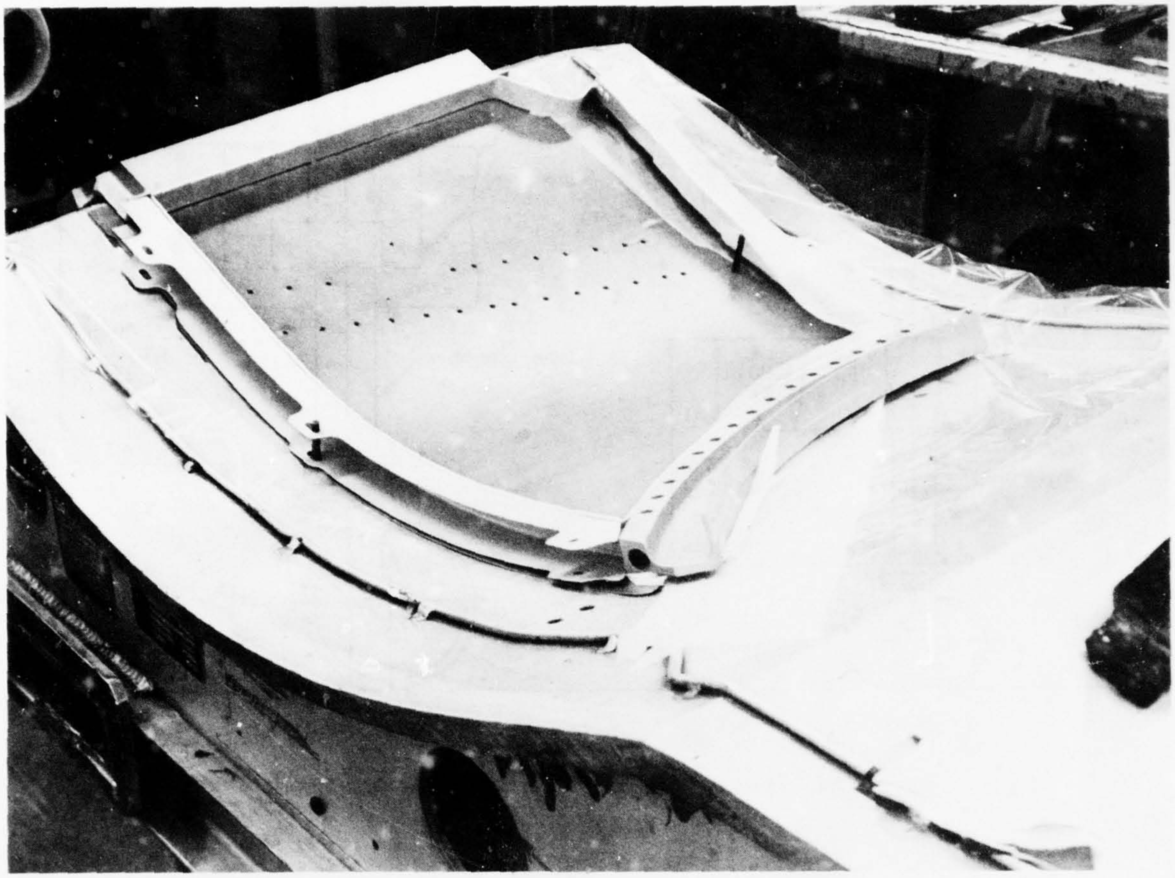


Figure 9-13.—Welded Bonding Tool Showing Fork Lift Hole—Pinned Details in Place

9.3 FIBERGLASS LAMINATE TOOL FABRICATION

This section provides a step-by-step fabrication sequence for lay-up and cure of preimpregnated fiberglass tooling. The "wet lay-up" system may be substituted if this is desirable. Information and instructions for the wet lay-up process are available from suppliers of high temperature tooling resins. Examples of these are:

- Ren Plastics
  5656 S. Cedar
  Lansing, Michigan 48909
- Hysol
  15051 E. Don Julian Rd.
  Industry, CA 91744
- Hexcel-Resolin
  20701 Nordhoff St.
  Chatsworth, CA 91311

AD-A055 684 BOEING COMMERCIAL AIRPLANE CO SEATTLE WASH F/G 1/3
ADHESIVE BONDED AEROSPACE STRUCTURES STANDARDIZED REPAIR HANDBO--ETC(U)
DEC 77 R E HORTON, J E MCCARTY F33615-73-C-5171
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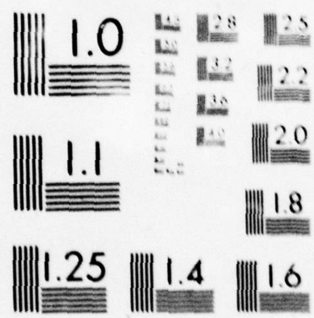


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

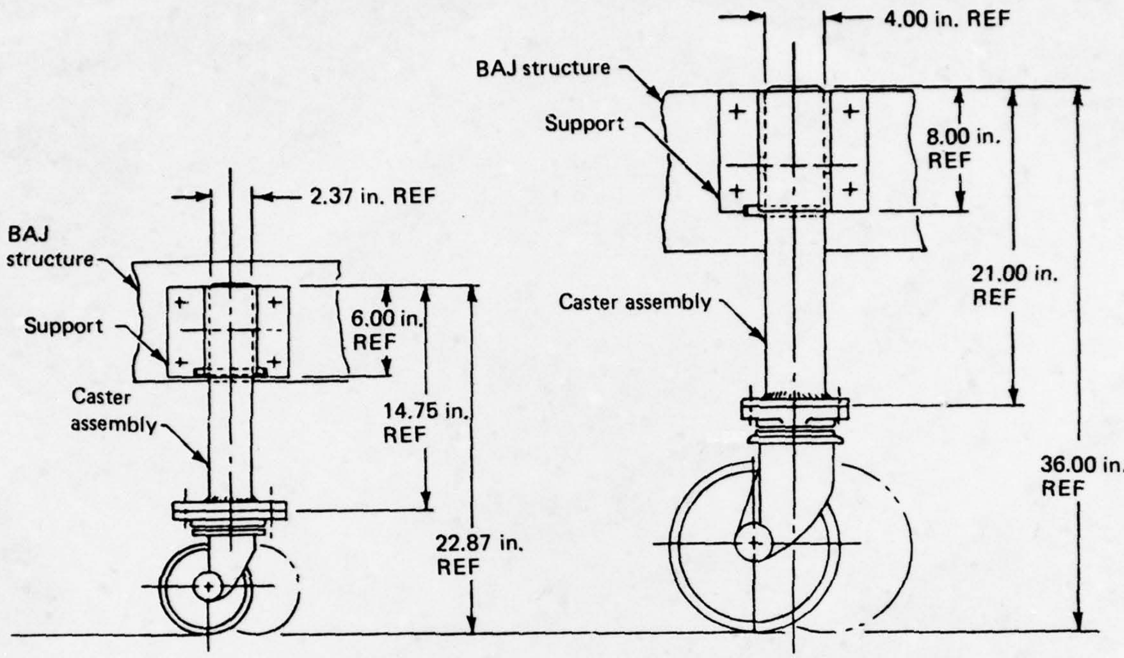


Figure 9-14.—Typical Caster and Caster Support Assemblies

The procedure for fabricating the tool is briefly illustrated in figure 9-15. The detailed procedure is as follows:

1. Either the damaged part or an undamaged duplicate part may be used to mold the tool surface. Assuming the former is selected, inspect the damaged area for holes, nicks, protrusions, dents, etc. Prepare the surface for filling by removing all the protruding fragments and smoothing out other areas. Filler resins or potting compounds will be used to temporarily return the surface to its original shape. The example of a contoured surface panel with a damaged area to be filled is shown in figure 9-16.

2. Fill surface defects with

   - Fast-Weld #10, which is a fast setting (10-minute) paste adhesive from Ren Plastics, Lansing, Michigan

   - Epocast 15-11/9614 catalyst, Furane Plastics, Inc. 4516 Brazil St., Los Angeles, Calif. 90039 (24-hour cure), or

   - an equivalent material

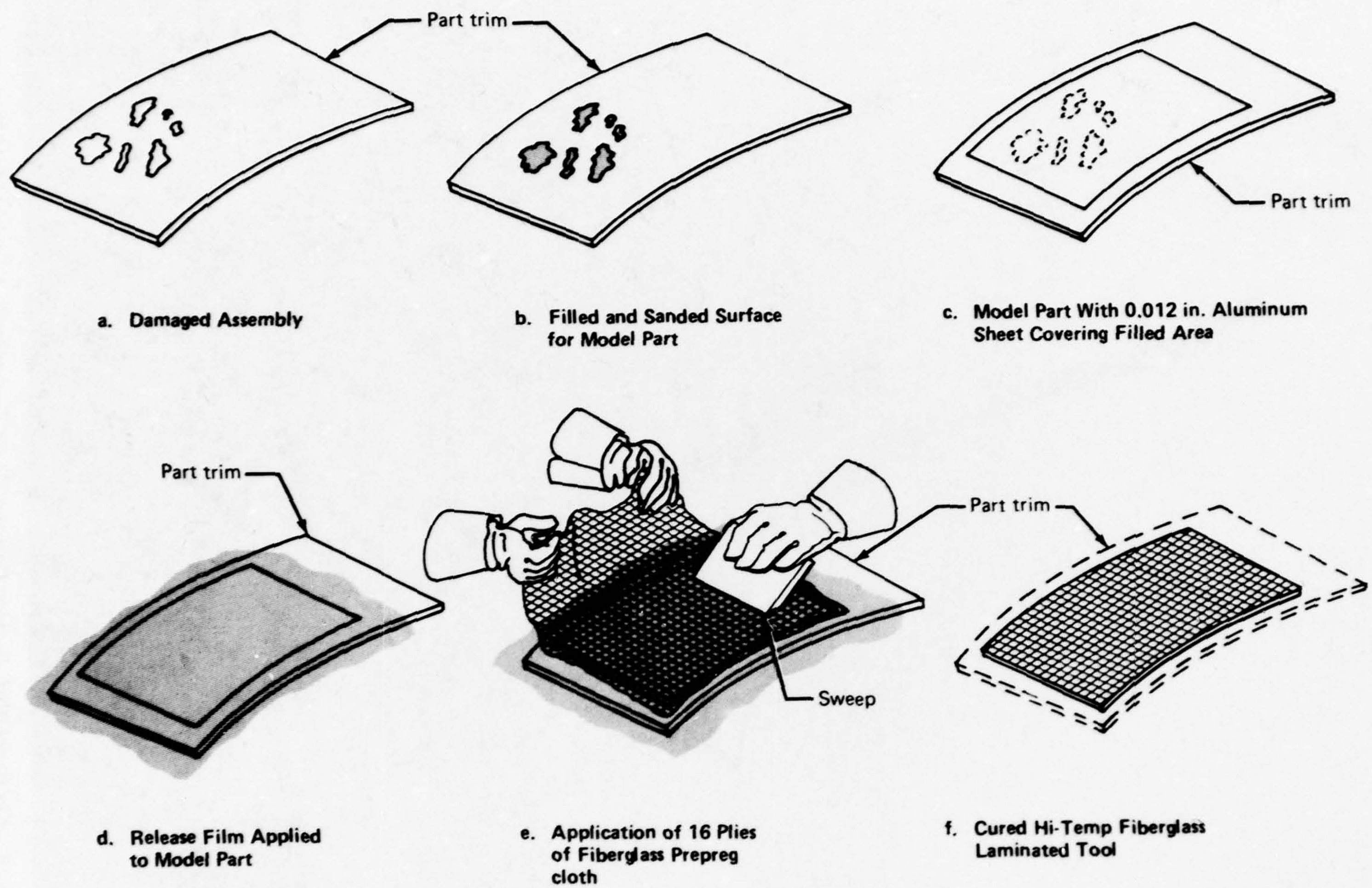


Figure 9-15.—Fabrication Method—Low-Cost Laminated Tool

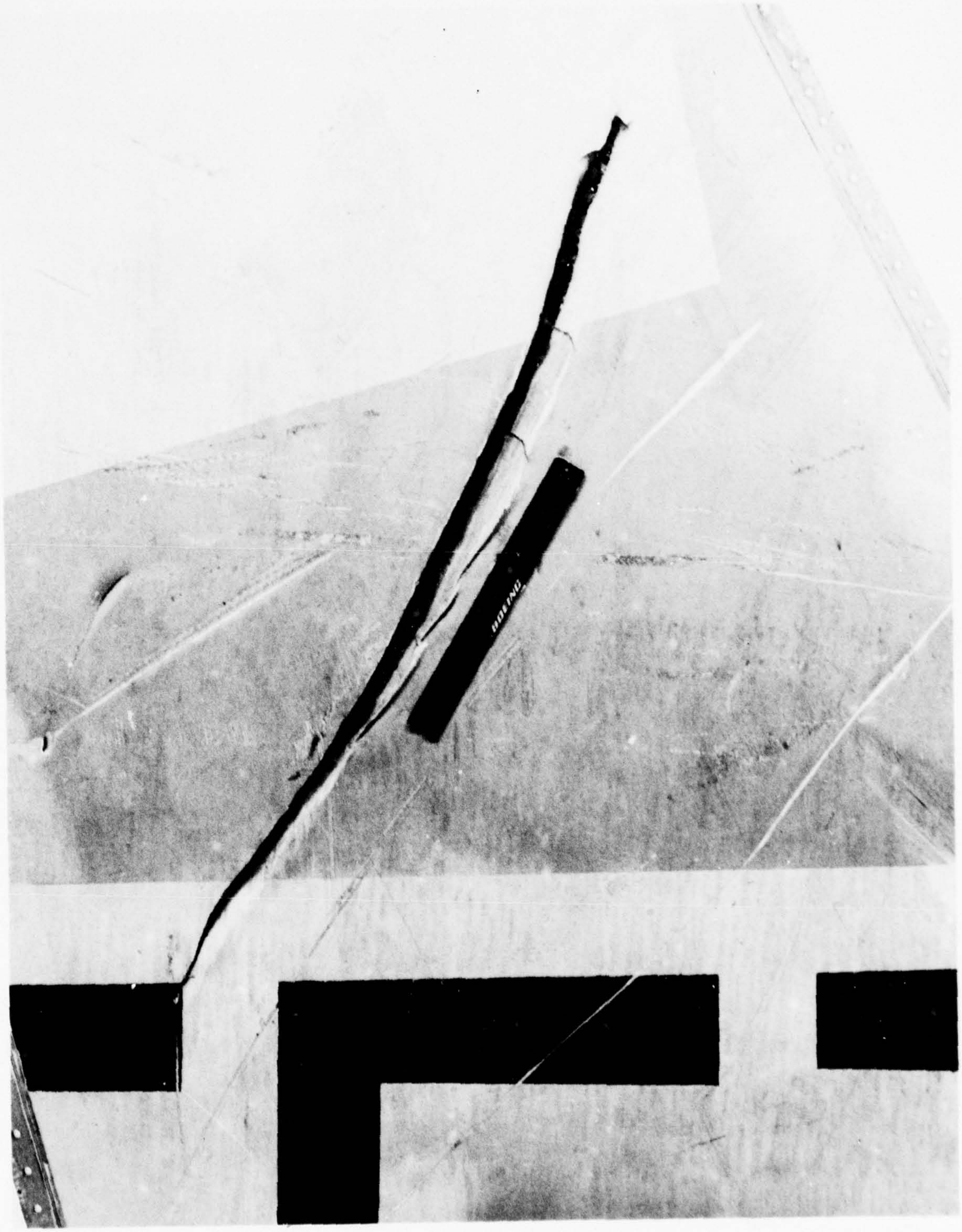


Figure 9-16. – Fin Panel With Surface Damage To Be Temporarily Filled to Mold Bonding Tool

3. Machine, grind, file, or sand the surface to a smooth, faired contour i.e., the original contour. This is illustrated for the previously noted panel in figure 9-17.

4. If the part has single-contoured curvature, it may be further smoothed out by covering the defective area with a thin (0.020-in.) sheet of heat-treated aluminum alloy. Attach the aluminum with double-backed tape. Extend the sheet beyond the repair area. This is illustrated in figure 9-18.

5. Position a layer of release film (FEP, TFE, etc.), nonperforated, over the aluminum sheet, sweep out all trapped air and wrinkles, making a surface to surface contact. Hold in place with high temperature masking tape.

6. Lay out, cut and fit a mylar template to the size of fiberglass fabric required for the laminate.

   NOTE: When a very large laminated tool is being fabricated, the fiberglass fabric will have to be spliced by joints butted together. In this case, a mylar template may not be useful and careful hand measurement may be required.

7. Remove the preimpregnated fabric from refrigerated storage. Condition to room temperature before opening the sealed packaging (sec. 1.2.5).

   Suggested supplier product designation

   - IP81-F-161-108 or IP43-F-161-108 prepreg fiberglass
     Hexcel Corp., Coast Mfg. Co. Div., 11711 Dublin Blvd., Dublin, Calif. 94566.

   - USP-E-720E-181, Volan A, or USP-E-720E-143 Volan A, prepreg fiberglass.
     U.S. Polymeric, Inc., 700 E. Dyer Rd., P.O. Box 2157, Santa Ana, Calif. 92797

8. Unroll enough fiberglass prepreg to cover the desired tool area. Place the mylar template on the material. Cut the 12 to 16 plies of fabric required to build up the tool thickness.

   NOTE: The warp and weave orientation of the fiberglass can be alternated to add balanced stiffness to the tool body.

9. Position each ply of prepreg fiberglass on the prepared part surface. Sweep out air bubbles, wrinkles, and kinks. (A plastic applicator, P.A.-1 made by 3M, or equivalent, may be useful.) Continue lay-up until all plies are in place.

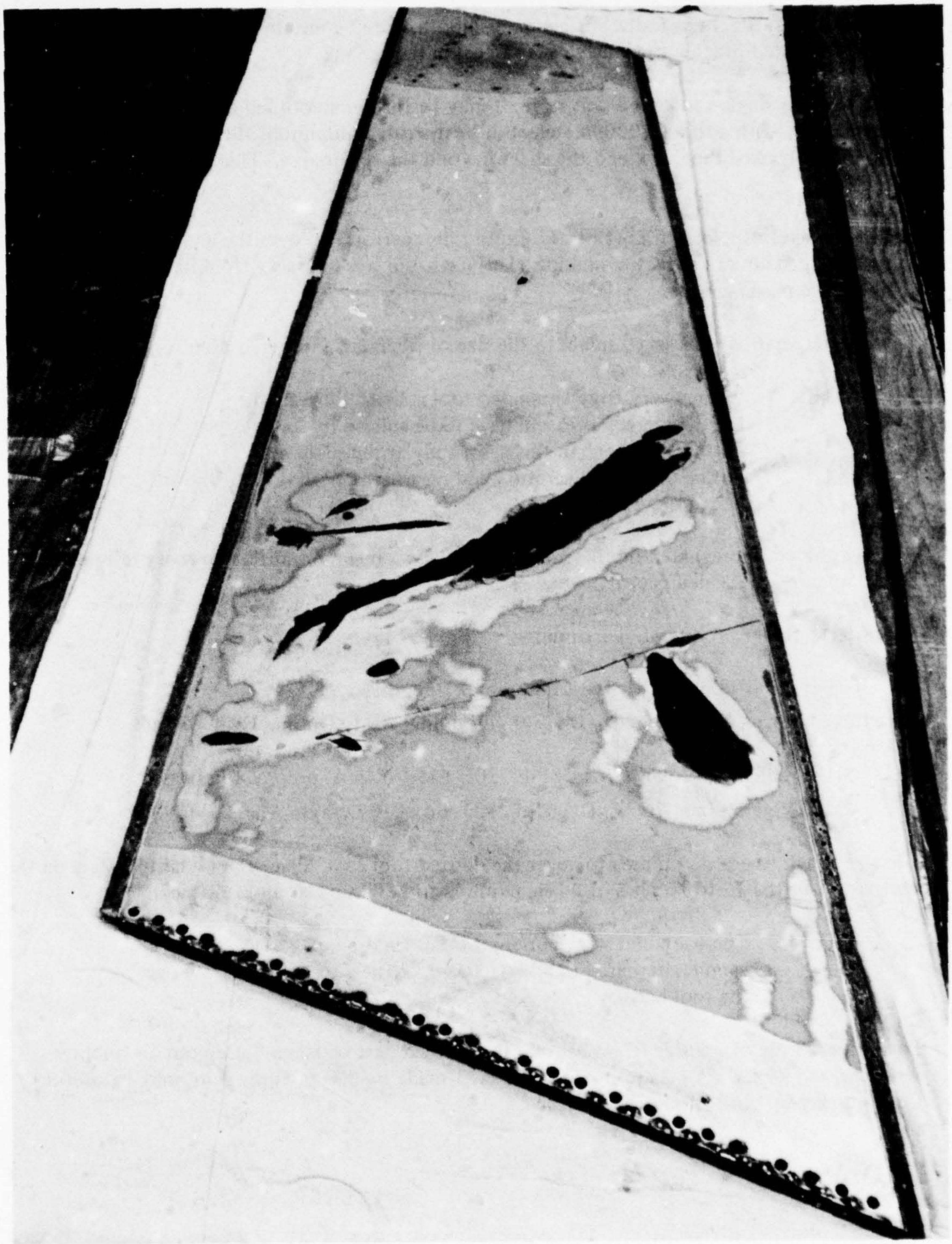


Figure 9-17.—Fin Panel With Damage Temporarily Filled and Smoothed

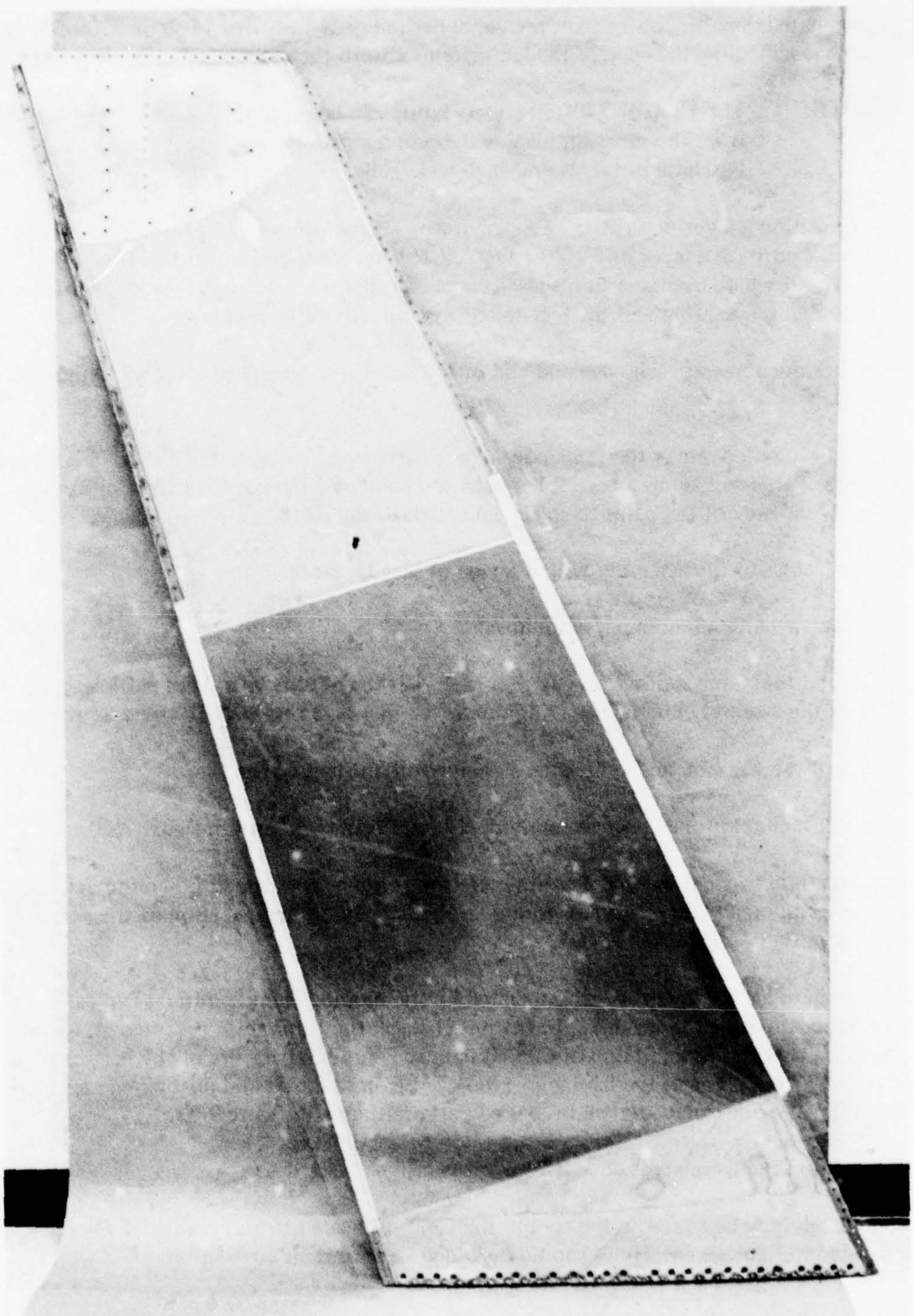


Figure 9-18.—Filled Fin Panel With Thin Metal Sheet Added for Additional Smoothness

10. If the laminate is smaller in size than the panel periphery, a 4-ply dry 1500 or 7500 fiberglass cloth strip is laid along the edge of the laminate to absorb the resin bleed out. (See fig. 9-19.)

NOTE: The 1500 or 7500 fiberglass fabric can be obtained from the same supplier as the prepreg material. Purchase in 1-1/2- or 2-inch-wide rolls.

11. Cut and position a layer of FEP or TFE perforated release film over the laminate and edge strips. Next position a layer of PVC- or FEP-coated fiberglass cloth over this film. This latter is optional but where excess resin bleed-out occurs, it helps break up the bond layer between the perforated release film and the bleeder cloth (applied as the next layer).

12. Place a thermocouple at each edge and end of the laminate. Secure in place with high temperature masking tape.

13. If the part is painted, cover the remainder of the surface with a layer of FEP or TFE nonperforated release film. This will act as a barrier between the paint and the covering layer of bleeder cloth. There is a tendency of the paint to soften and stick to the cloth.

14. Cover both sides of the assembly with 4 layers of bleeder cloth.

15. Prepare the envelope vacuum bag as follows:

    a. Cut and fold a piece of nylon bag film such that the double layer is of sufficient size to cover the assembly and have a minimum of 12 inches excess width all around the assembly.

    b. Unfold the bag film and center the assembly on one half of the film.

    c. Install vacuum probes. An assembly ready for closure is shown in figure 9-20.

16. Seal the vacuum bag and complete the preparation for cure as outlined in section 7.11.1. A bagged assembly ready for precure is shown in figure 9-21. A cross section of the assembly is illustrated in figure 9-22.

17. Cure in an autoclave or oven as recommended by the prepreg manufacturer. Typically the cure process is accomplished in 2 stages. In the initial stage, the laminate is precured at a temperature that is somewhat less (a minimum of 50° F) than the cure temperature of the part being used as a mold. After the precure, the laminate is removed from the part and post cured at a higher temperature. A completed tool and repaired part are shown in figure 9-23.

18. After the cure, the laminate is checked for warpage.

Reinforcement can now be added to the tool in the form of beaded strips or webs of fiberglass cloth. This is illustrated in figure 9-24. Holes should be added to permit air circulation.

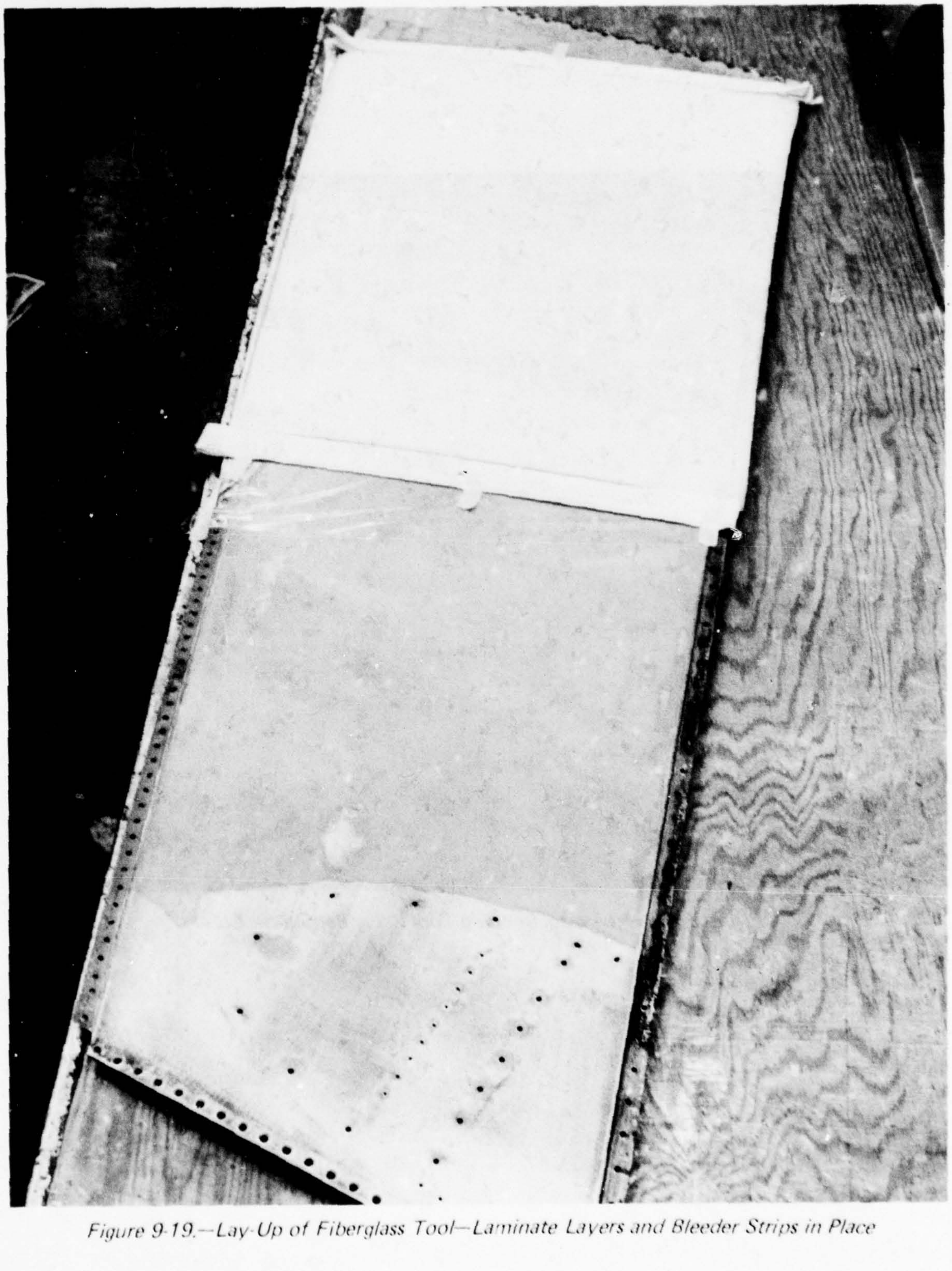


Figure 9-19.—Lay-Up of Fiberglass Tool—Laminate Layers and Bleeder Strips in Place

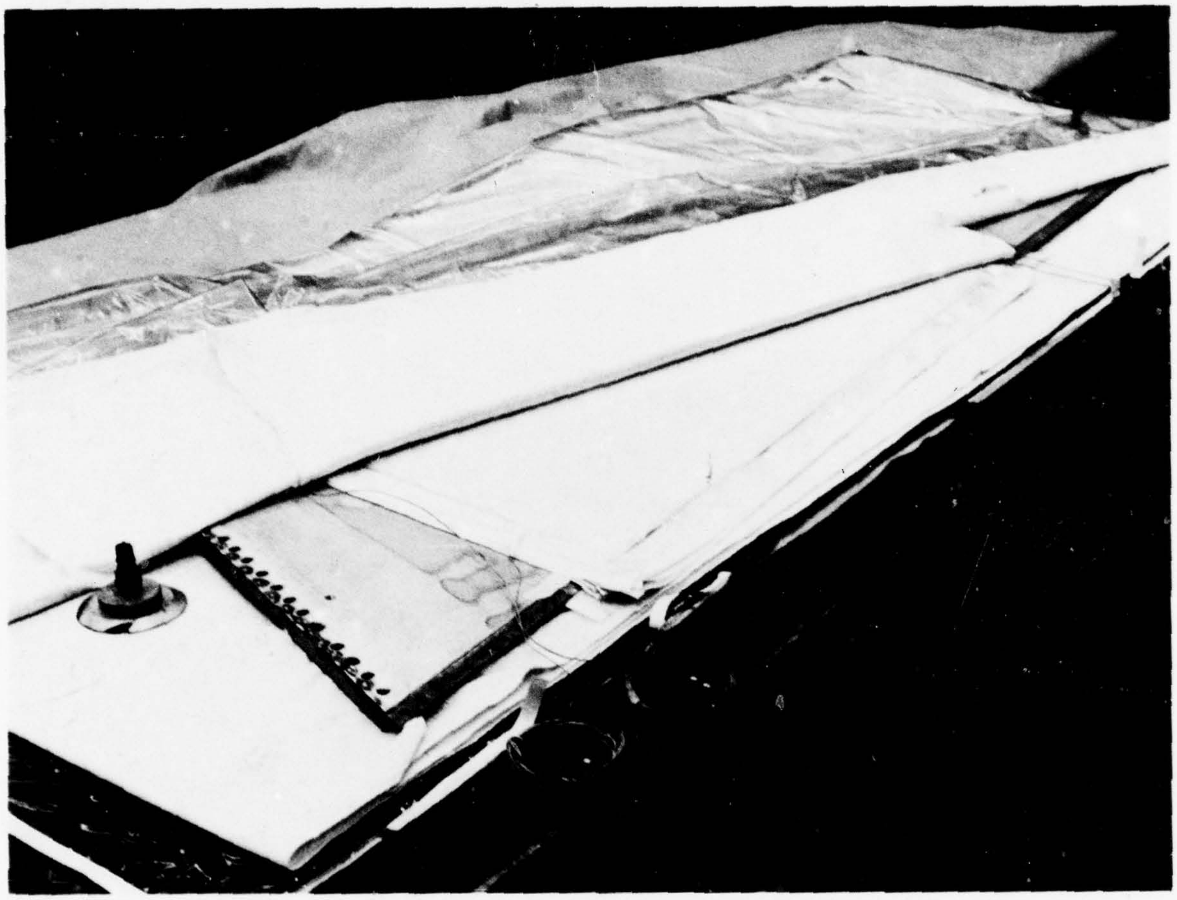


Figure 9-20. – Fiberglass Bonding Tool Being Bagged for Cure

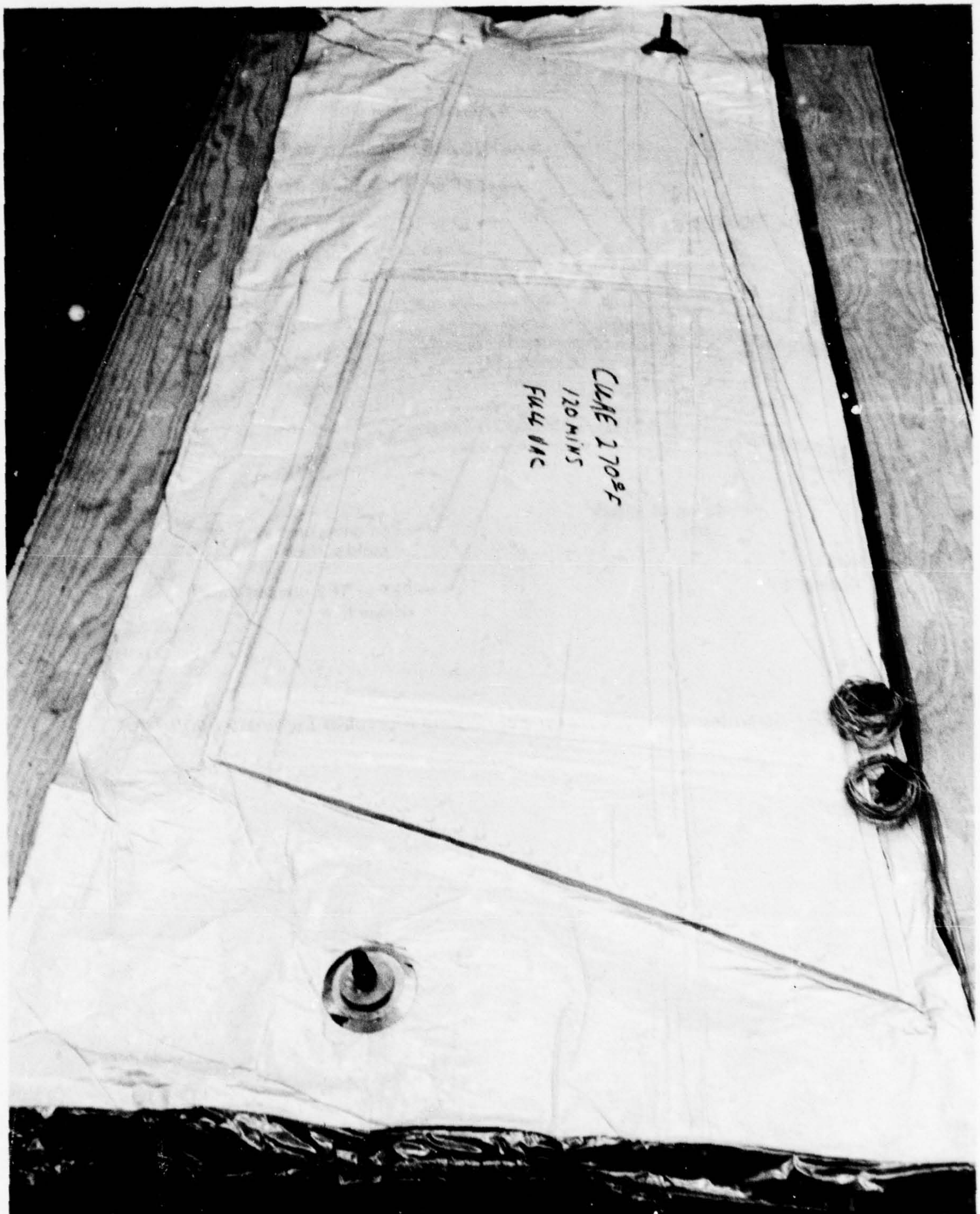


Figure 9-21.—Assembly Ready for Cure of Bonding Tool

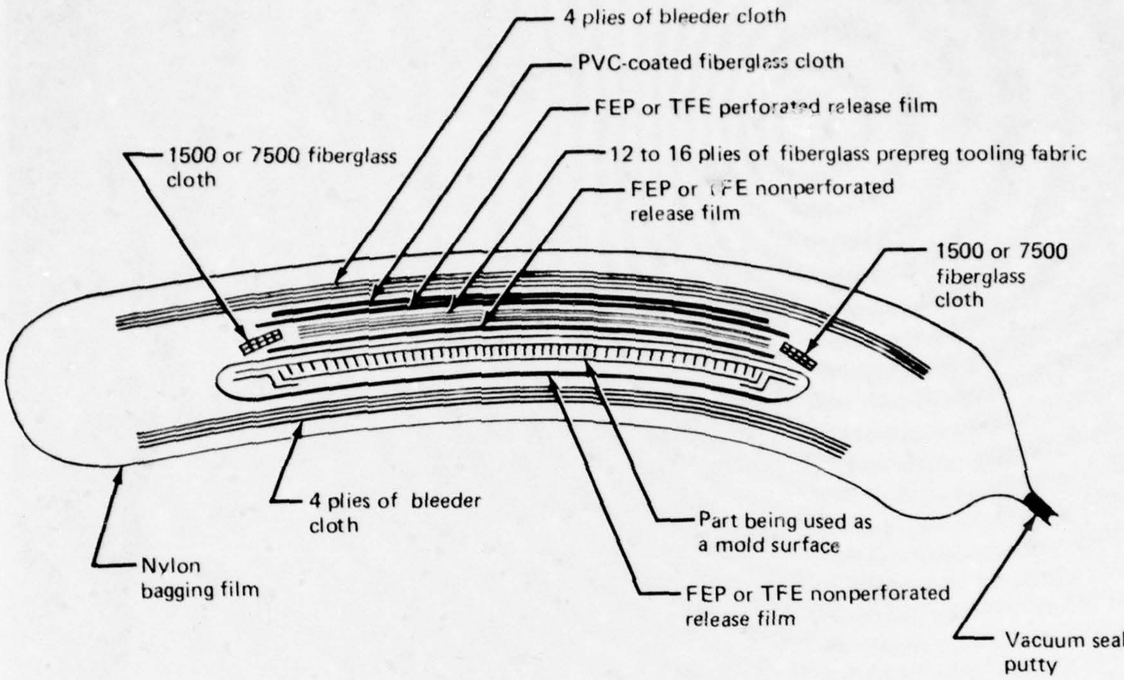


Figure 9-22.—Assembly Components for Fabricating Fiberglass Laminate Bond Tool

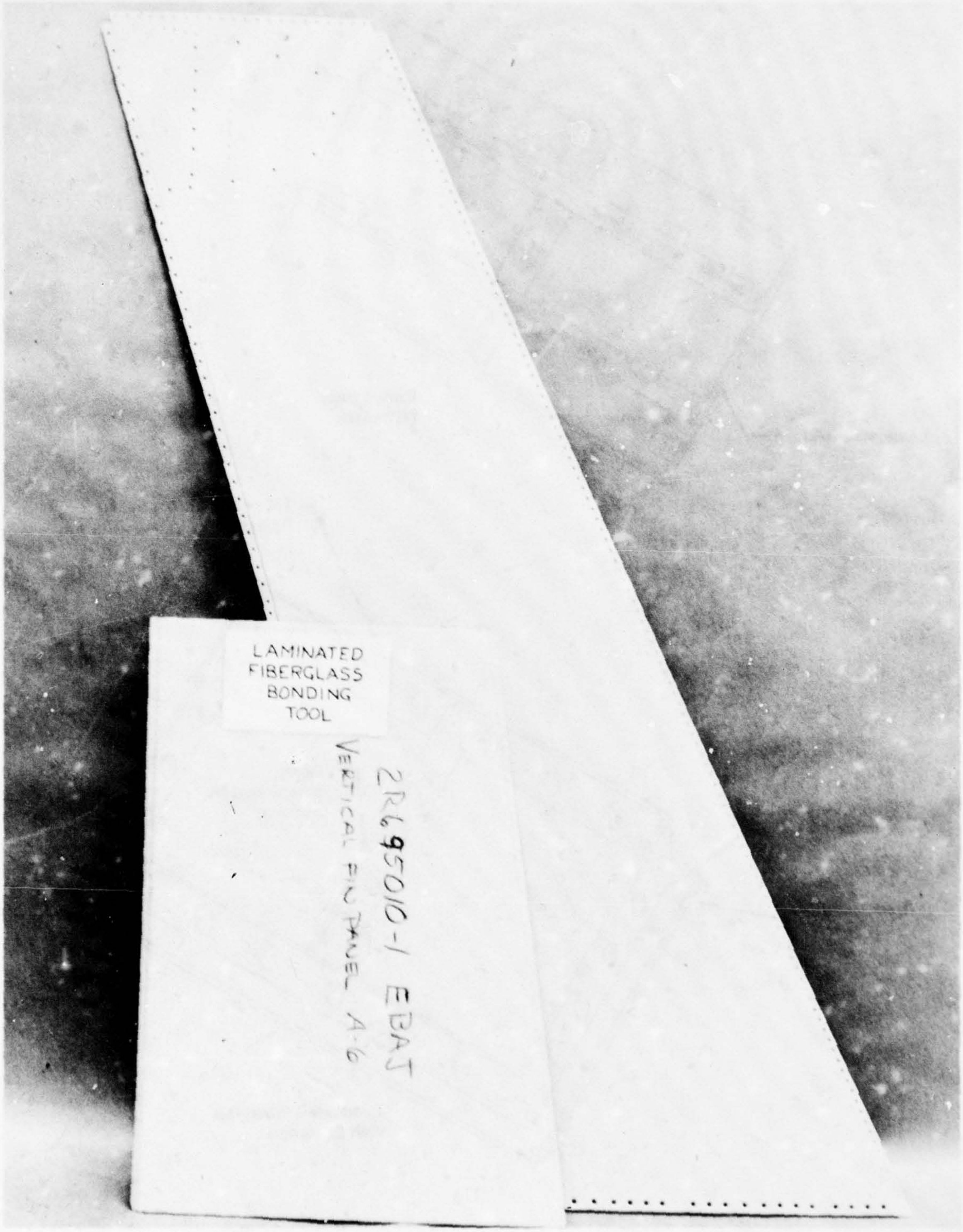


Figure 9-23.–Completed Fiberglass Bond Tool and Repaired Fin Panel

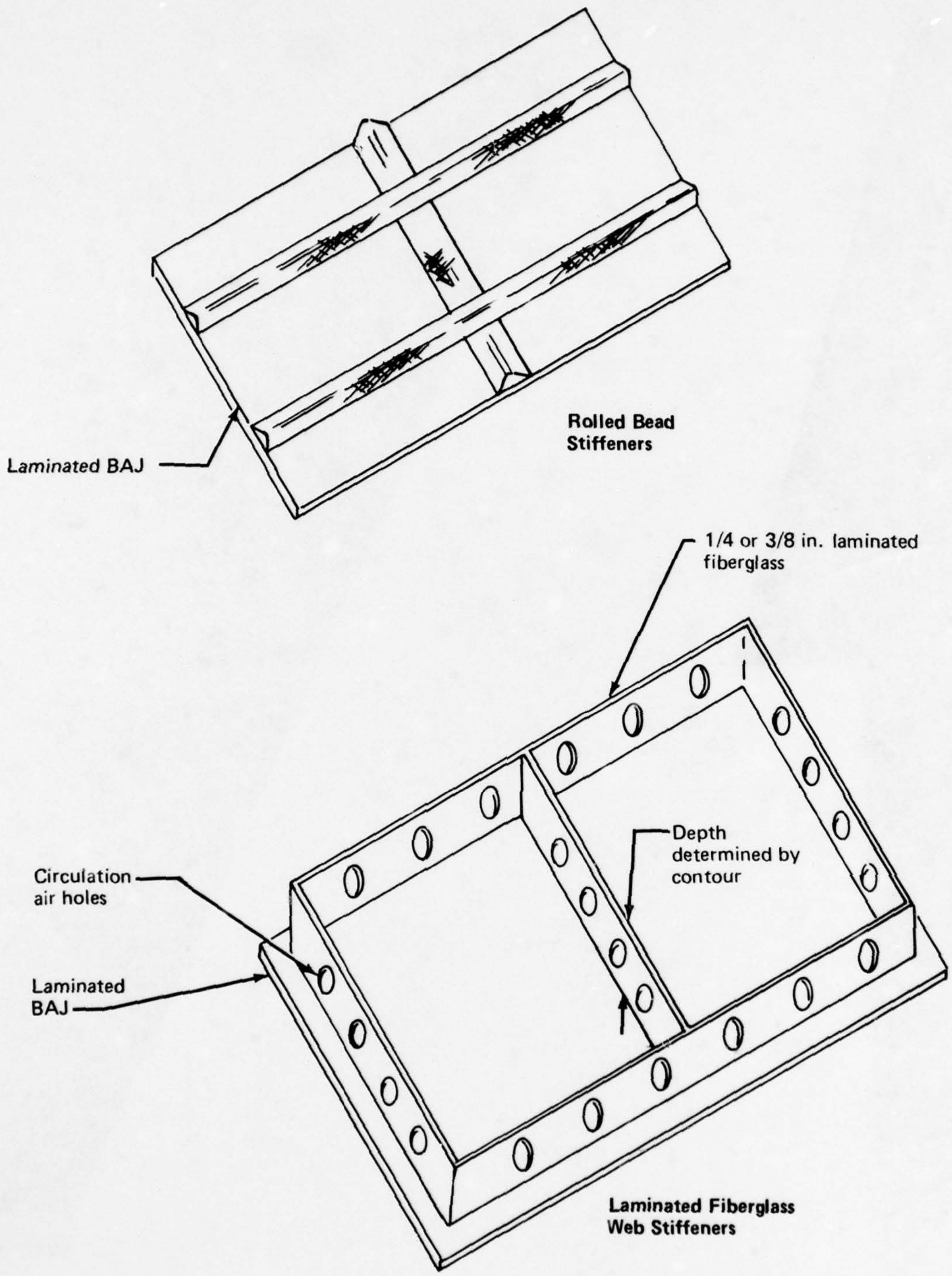


Figure 9-24.—Methods of Stiffening Fiberglass Laminate Tools

10. NONDESTRUCTIVE INSPECTION

10.1 GENERAL

10.1.1 INTRODUCTION

This section contains a description of nondestructive inspection (NDI) methods that are particularly applicable to the quality evaluation of bonded structural aircraft parts. These methods are directed towards the detection of defects which, if left undiscovered, might prevent the parts from fulfilling their designed functions. These methods provide a general guide based on past experience of engineering and in-service surveillance.

The typical or most commonly used techniques are included. Other techniques may be equally applicable. Responsibility for selection of techniques for a particular application rests with the using facility. General NDI procedures, techniques, and terminology are T.O. 33B-1-1. The –36 T.O.'s also provide NDI instructions for the inspection of airplane structures. Any deviations from these documents for a specific aircraft should be approved by the responsible engineering agency.

It is important to note that all NDI techniques are comparative (i.e., they give indications of one area being different from or the same as another). Reference standards are used by the inspector to evaluate changes that might indicate a defect. Care must be taken in the interpretation of change indications, however, since they may be due to changes in the structures (e.g., a foam splice, tapered core, chem-milled skin, or excess adhesive), the inspector must be familiar with the internal construction of the part to distinguish between defects and legitimate structural changes.

10.1.2 HOW TO USE THE NDI SECTION

The NDI instructions are presented in two categories. These are prerepair evaluation and postrepair examination. The instructions for prerepair evaluation are listed in section 2.0, Damage Assessment. The selection of the proper prerepair NDI technique may be done per tables 10-1 and 10-2. A guide for the post-repair examination is given in table 10-3. The subjects of NDI method applicability, personnel qualifications, test standards, definitions, terminology, and NDI symbols are discussed briefly as applicable to this manual.

10.1.3 TERMINOLOGY AND DEFINITIONS

Bondline—A layer of adhesive such as one located between two pieces of metal or between a metal face and honeycomb core.

Corrosion—A breakdown of the metal surface due to an electrochemical reaction. Almost all metals are subject to corrosion. Corrosion may be present in parts exposed to water and moisture, in parts without protective coating, and parts where dissimilar metals come in electrical contact.

Couplant—A sound couplant is a film of oil, grease, or water applied to a surface to provide a path for the passage of ultrasonic vibrations between the sound transmitter and the part being inspected.

Table 10-1.—Prepair Defect Inspection Methods

● Preferred

o Alternate

□ Limited alternate

		Visual	Tapping	Resonance	Ultrasonic, low freq, portable	Ultrasonic, low freq, through	Ultrasonic, high freq, pulse echo	Ultrasonic, high freq, through	X-ray	Eddy current	Acoustic emission	Ultrasonic/eddy current thickness gauging
Metal-to-metal honeycomb sandwich	Moisture, oil				□	o			●		o	
	Core corrosion				□	o	o	o	●		o	
	Core crushing	□			o	o		o	●			
	Face sheet delam	□	□	o	o	o		●				
	Back sheet delam	□			□	o		●				
	Void, porosity		□	o	o	o		●				
	Skin cracks	□								●		
	Face sheet corr, internal						o				●	
Metal skin-to-nonmetal core honeycomb sandwich	Moisture, oil				□	o			●		o	
	Corrosion				□	o		o	●	o	o	
	Core crushing	□			o	o	o	o	●			
	Face sheet delam	□	□	o	o	o		●				
	Back sheet delam	□			□	o		●				
	Void, porosity		□	o	o	o		●				
	Skin cracks	□								●		
	Face sheet corr, internal						o				●	
Metal-to-metal single laminate	Bondline corrosion			o	□	o	o	o		o	●	o
	Delamination		□	●	o	o	□	●				
	Voids		□	●	o	o	□	●				
	Skin cracks	□								●		
Metal-to-metal multilaminate	Bondline corrosion			o	□	o	o	o		o	●	o
	Delamination		□	o	□	o	□	●				
	Voids		□	o	□	o	□	●				
	Skin cracks	□								●		

Table 10-2.—Inspection Technique Selection Guide

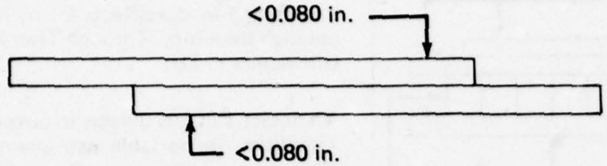
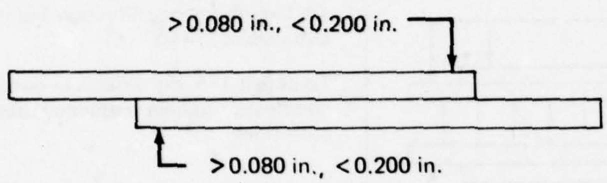
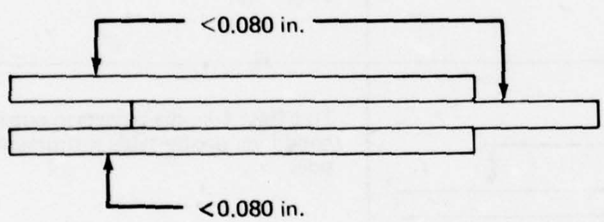
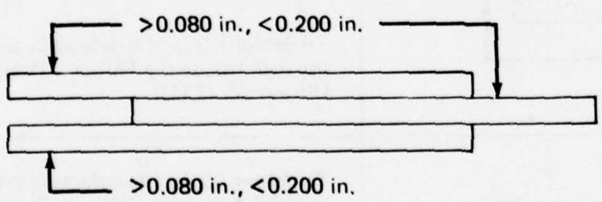
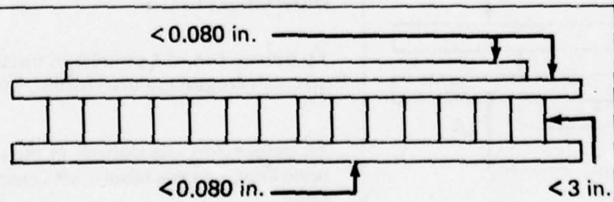
Type of structure	Recommended inspection technique
	To detect 1 -in.-dia defects, use portable instruments (such as Sondicator, Harmonic bond tester, etc) To detect 1/2-in.-dia defects, use high frequency ultrasonics To detect 1/4-in.-dia defects, use high frequency Through Transmission Ultrasonics (TTU)
	To detect 2-in.-dia defects, use portable instruments To detect 1-in.-dia defects, use high frequency ultrasonics To detect 1/2-in.-dia defects, use high frequency Through Transmission Ultrasonics (TTU)
	To detect 1-in.-dia defects, use portable instruments, both sides To detect 1/2-in.-dia defects, use high frequency ultrasonics, both sides To detect 1/4-in.-dia defects, use high frequency Through Transmission Ultrasonics (TTU)
	To detect 2-in.-dia defects use portable instruments, both sides To detect 1-in.-dia defects, use high frequency ultrasonics, both sides To detect 1/2-in.-dia defects, use high frequency Through Transmission Ultrasonics (TTU)
	To detect 1/2-in.-dia defects in any bondline, use high frequency Through Transmission Ultrasonics (TTU) To detect 1/2-in.-dia defects in outside bondlines, use portable instruments, both sides

Table 10-2.–(Continued)

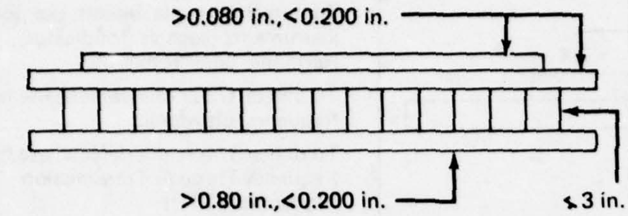
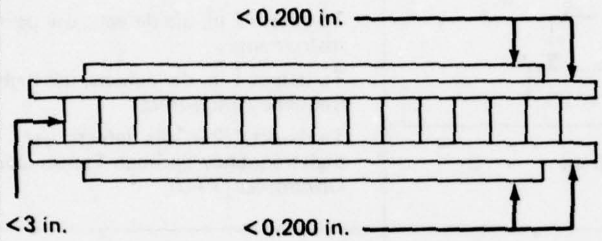
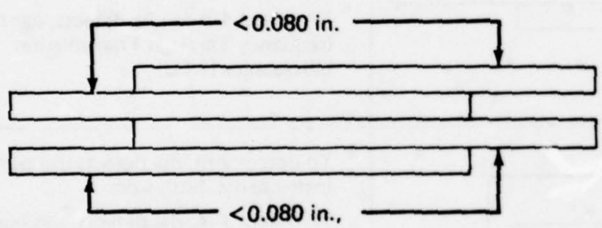
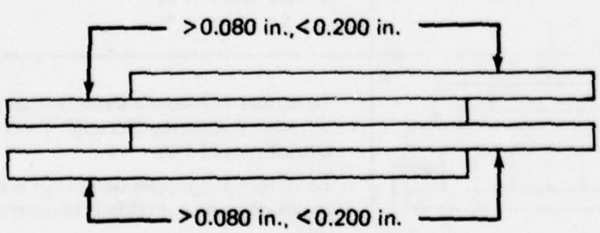
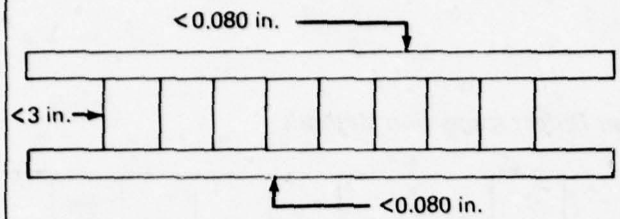
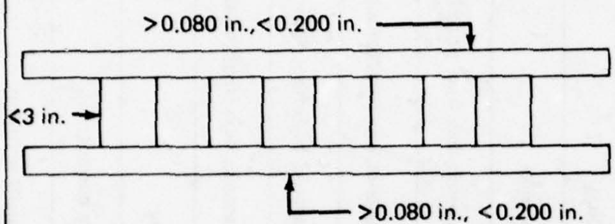
Type of structure	Recommended inspection technique
	To detect 1-in.-dia defects in any bondline, use high frequincy Through Transmission Ultrasonics (TTU) To detect 1-in.-dia defects in outside bondlines, use portable instruments,both sides
	To detect 1-in.-dia defects in any bondline, use high frequency Through Transmission Ultrasonics (TTU) To detect 1-in.-dia defects in outside bondlines, use high frequency ultrasonics, both sides To detect 2-in.-dia defects in outside bondlines, *use portable instruments*, both sides
	To detect 1-in.-dia defects in outside bondlines, use portable instruments, both sides To detect 1-in.-dia defects in center bondlines, use high frequency ultrasonics, either side To detect 1/2-in.-dia defects in any bondline, use high frequency Through Transmission Ultrasonics (TTU)
	To detect 1/2-in.-dia defects in any bondline, use high frequency Through Transmission Ultrasonics (TTU) To detect 1-in.-dia defects in outside bondline use high frequency ultrasonics, both sides To detect 2-in.-dia defects in outside bondlines, use portable instruments, both sides

Table 10-2.–(Concluded)

Type of structure	Recommended inspection technique
	To detect 1-in.-dia defects in either bondline, use portable instruments, both sides To detect 1/2-in.-dia defects in either bondline, use high frequency Through Transmission Ultrasonics (TTU)
	To detect 1-in.-dia defects in either bondline, use high frequency ultrasonics

Crack–A break or split in the part without complete separation. Cracks may be found in parts which have been ground, heat-treated, fatigued, or stress-corroded.

CRT (Cathode Ray Tube)–Provides visual display of ultrasonic information.

C-scan–Plan view scan of the part showing defect size and location.

Defect–A discontinuity, or fault, that is detrimental to the serviceability of the part or material in which it is contained.

Discontinuity–An interruption in the normal physical structure of a part. It may be in the form of a crack, forging lap, fold, seam, porosity, disbond, etc. A discontinuity may or may not affect the usefulness of the part.

Delamination–The separation of layers in a lamination because of failure of the adhesive, either in the adhesive itself (cohesive) or between the adhesive and the adherend interface (adhesive).

Inclusion–Impurities embedded in the material in the forming stage. The inclusions can be deep in the part or near the surface. Normally, they will not have any effect on the strength of the part, but, when they occur in areas of high stress or in certain special locations, they may be cause for rejection of the part.

Nondestructive inspection–Examination of structural parts and components for surface and subsurface defects without damaging the structure.

Table 10-3.—Postrepair Defect Inspection Methods

● Preferred

o Alternate

□ Limited alternate

		Visual	Tapping	Resonance	Ultrasonic, low freq, portable	Ultrasonic, low freq, through	Ultrasonic, high freq, pulse echo	Ultrasonic, high freq, through	X-ray	Eddy current	Acoustic emission
Metal-to-metal honeycomb	Face sheet delam	□	□	□	o	o		●			o
	Back sheet delam				□	o		●			
	Void, porosity	□	□	□	o	o		●			
	Void in potting								●		
	Core defect				o	o		●	●		
Metal skin-to-nonmetal core honeycomb sandwich	Face sheet delam	□	□	□	o	o		●			o
	Back sheet delam				□	o		●			
	Void, porosity	□	□	□	o	o		●			
	Void in potting								●		
	Core defect							●	●		
Metal-to-metal single laminate	Delamination		□	●	o	o	o	●	o		
	Voids		□	●	o	o	o	●	o		
Metal-to-metal multilaminate	Delamination		□	o	□	o	o	●	o		
	Voids		□	o	□	o	o	●	o		

Void—Any unbonded area which is supposed to be bonded. Many subdefinitions of voids are often given, such as lack of adhesive, gas pocket, misfit, porosity, etc. This section of the manual makes no distinction between terms but groups them in a general term "void".

The following definitions of levels of nondestructive test inspectors are from MIL-STD-410D and are included here for convenience:

NDT Level I—A Level I individual shall know the practical aspects of the certified NDT method; the importance of following procedures exactly and be able to perform operational type tests using techniques specified by Level II or III personnel. He shall be knowledgeable of the cleaning and any other necessary preparation of parts before or after inspection. He shall be proficient in setting up and conducting the required test of the material, part, or assembly.

NDT Level II—In addition to Level I requirements, a Level II individual shall be qualified to direct and carry out tests in the method certified. He must also be able to set up and calibrate equipment (where applicable), read and interpret standards and specifications and contracting agency documents. He shall be thoroughly familiar with the scope and limitations of the method, and shall have the ability to apply detailed techniques to products or parts within his limit of qualifications. He shall be able to organize and report test results. He shall know practical theory and be familiar with utilizing techniques. He must be aware of the need for and the limitations of reference standards. He must be familiar with the type and location of expected defects for the fabrication process used to make the parts.

NDT Level III—In addition to Level I and Level II requirements, a Level III individual shall be capable of establishing techniques, interpreting specifications and codes designating the particular test method and techniques to be used, and interpreting the results. He shall be capable of evaluating the results in terms of existing codes and specifications and shall have sufficient practical background in applicable materials technology to assist in establishing tests and acceptance criteria when none are otherwise available. When applicable, he shall be knowledgeable in the other nondestructive testing methods. He shall be capable of preparing, conducting and grading examinations for qualifying NDT Level I, II and III personnel. He shall be able to determine if an individual has used the correct procedure and to recognize the use of improper methods or techniques.

10.1.4 PERSONNEL QUALIFICATIONS

Nondestructive inspection of adhesive-bonded assemblies is relatively new as compared to inspection where other NDI is employed (e.g., penetrant and magnetic particle). The effectiveness of these techniques depends on their proper application by trained and qualified operators. MIL-STD-410D outlines the qualification and certification requirements for NDI personnel. Unfortunately, it does not cover the requirements applicable to adhesive bonded assemblies. Until these requirements are also incorporated in MIL-STD-410, the responsibility to ensure qualified operators depends on the user of these techniques. It is recommended that an equivalent of an NDI Level III determine the type of technique to be used for pre- and post-damage repair inspection of adhesive bonded assemblies. A Level I or II inspector will conduct the NDI examination. The Level II inspector will evaluate the inspection results for determination of repair requirements or acceptance or rejection of the repaired parts.

10.1.5 TEST STANDARDS

There should be at least two basic standards, (1) metal-to-metal with a known void, and (2) metal-core-metal with known void, to check the functioning of the instrument.

Preferred Standards

Test standards to calibrate and standardize the bond inspection instruments are very essential. An inspection technique is usually as good as the test standards. In ideal conditions, the test standard with known voids of selected sizes should closely duplicate the structure to be inspected. The laminated skins should be of the same thickness and the honeycomb core should be of the same thickness and density. Other variations such as tapered core, chemically milled skins and doublers, etc., should be incorporated in the test standard. Except for implanted defects, the test standard for adhesive-bonded structures should be fabricated in the same manner as the bonded assembly. The void or defect should be introduced in the same bondline as that to be inspected in the structure. This is typically accomplished by replacing the adhesive patch with a patch of teflon or parting film approximately the same size and thickness as the cured adhesive. Multiple layers of teflon or parting film should be used to achieve the proper thickness and to assure that a true disbond is incorporated (teflon or parting film will not adhere to itself).

> NOTE: Teflon may bond to the part and not make a good disbond. If this happens, the standard shall be refabricated.
>
> As an alternate, multiple layers of Kapton film have also been suggested to create a realistic bondline defect.

There are other methods of creating voids which have had some success. One of these is to machine an area from one of the metal substrates equal in size to the void. Another method is to replace a patch cut from the adhesive with a piece of precured adhesive of the same size and thickness. A third method, in the case of honeycomb, is to crush the core or machine the core so as to eliminate the contact between the core and the metal layer. Replacing the adhesive patch with a patch of teflon or parting film is preferred.

Substitute Standards

When the ideal test standards are not available, some other standards which are similar in structure to the part being tested may be used. However, honeycomb standards shall not be used for metal-to-metal laminate structure and vice versa.

Inspection Without Standards

When standards are not available, a known undamaged area can be used as the standard. To inspect the repaired area, compare it to unrepaired area. The instrument reading may change due to structure changes resulting from the repair. Repeated inspection scans must be conducted under various instrument settings and the inspection should be verified by another type of instrument. A knowledge

of the part configuration (i.e., number of bondlines, adhesive thickness, skin thickness, etc.) is essential in interpretation of test results.

10.1.6 PREREPAIR INSPECTION

Most mechanically damaged areas can be detected visually; however, the extent and the outline of any damage require a careful evaluation. The following guidelines should be followed when applicable:

1. Outline the damaged area after visual examination.
2. Verify and revise the outline by conducting a tap test.
3. Verify further by using a portable NDI instrument such as the Harmonic Bond Tester or the Sondicator.
4. On metal-to-metal laminations, the Fokker Bond Tester can usually trace a well-defined outline. Careful cleaning is required to remove the couplant after inspection if this method is used.
5. If there is a visible crack in the skin, the extent of the crack can be determined by using an eddy current inspection.
6. If the damage is in the honeycomb section, an X-ray examination should be conducted to determine the extent of core damage and/or moisture in the core.
7. If the damage is in the adhesive potting or foam-spliced areas, an X-ray inspection is recommended.
8. If the damage is in a multilaminate area, through-transmission ultrasonic inspection is recommended.
9. If the damage is in the multiple bondline of honeycomb structure, through-transmission ultrasonic inspection is recommended. The exposed areas must be sealed off to prevent water entry.
10. Use tables 10-1 and 10-2 for selection of the appropriate nondestructive inspection technique.

10.1.7 POSTREPAIR INSPECTION

Postrepair inspection should be conducted to determine that no area has been left unbonded and no additional delamination resulted during the cure cycle. The selection of NDT techniques should be per tables 10-2 and 10-3. The inspection procedure should be guided by whether or not test standards are available. The following guidelines shall be followed when applicable:

1. Conduct visual inspection of the repaired area for obvious defects.
2. Conduct NDT with one or more portable instruments. The selection of the instrument should be per tables 10-2 and 10-3.
3. On metal-to-metal bonded repairs (especially on narrow laminated steps) the Fokker Bond Tester inspection method should be considered.

4. If the repaired area has adhesive potting or a foam splice in the honeycomb area, X-ray examination is recommended.

5. If the repaired area consists of multilaminate or multiple bondlines in the honeycomb area, ultrasonic through-transmission is most definitive.

6. When standards are not available, the repaired area may be compared to an unrepaired area. The instrument readings may change due to structure changes resulting from the repair.

Repeat the inspection scan using various instrument settings and verify inspection results with another type of instrument.

10.2 GENERAL DESCRIPTION OF NDI METHODS AND EQUIPMENT

10.2.1 METHOD SENSITIVITY

Defect detection sensitivity between techniques with respect to defect size and location changes with changing conditions such as part complexity, operator experience, etc. Most instruments may be successful in detecting the majority of defects most of the time. However, in some instances special techniques and skills are needed to conduct a reliable inspection.

Figures 10-1, 10-2, 10-3, and 10-4 show relative capabilities of several techniques.

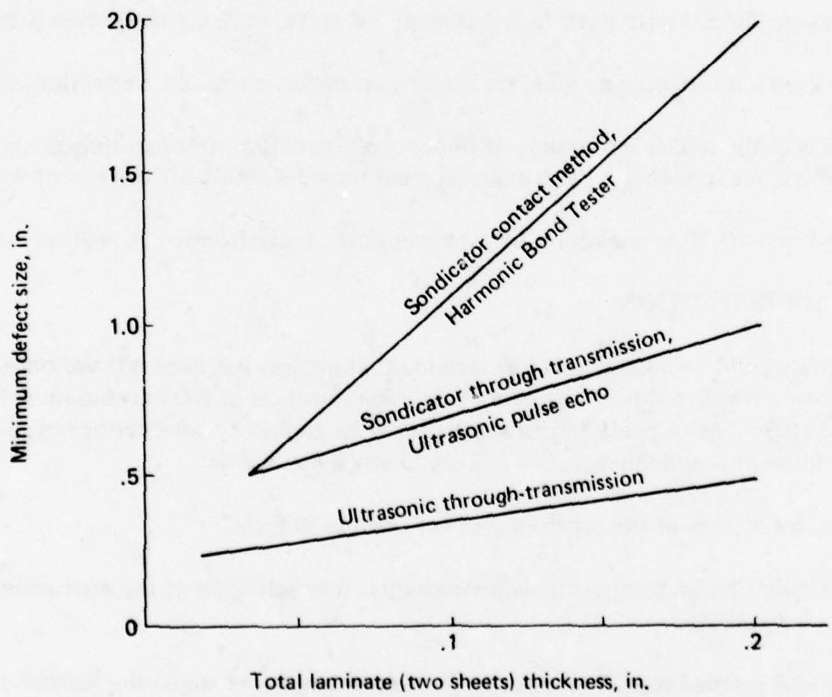
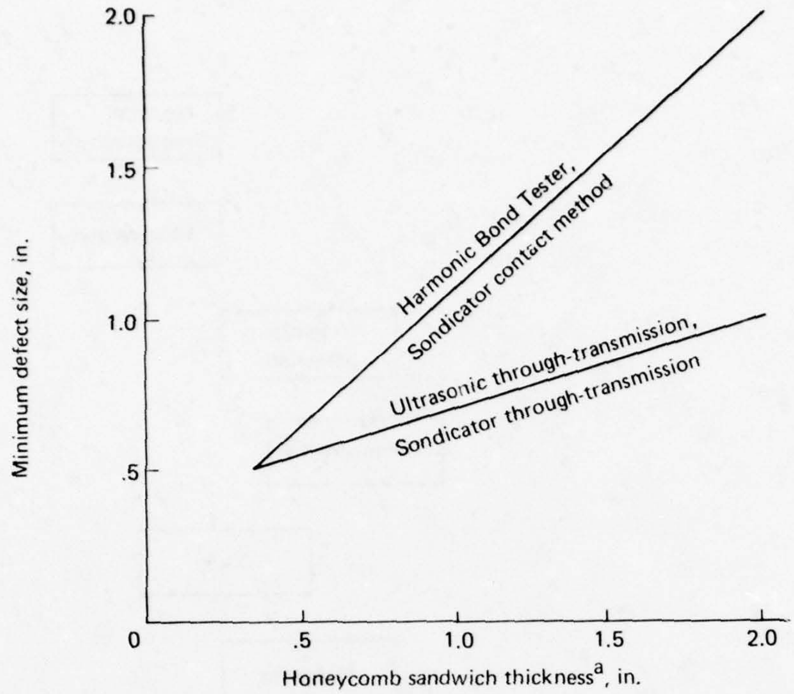


Figure 10-1.—Relative Instrument Sensitivity—Bonded Laminate Inspection



[a] Face thickness less than 0.080 inches

Figure 10-2.—Relative Instrument Sensitivity—Bonded Sandwich Inspection

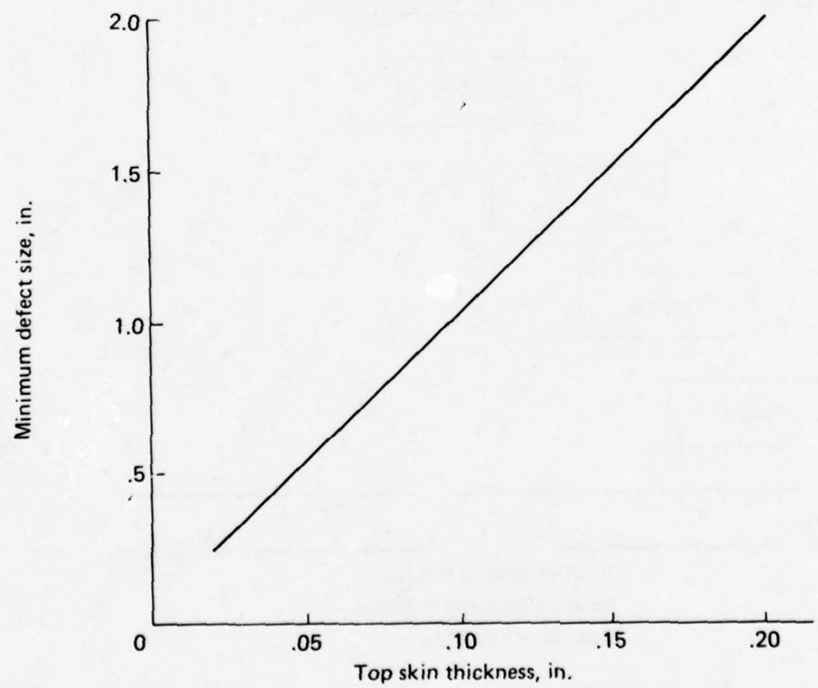


Figure 10-3.—Fokker Bond Tester Sensitivity—Bonded Laminate (Two Sheets) Inspection

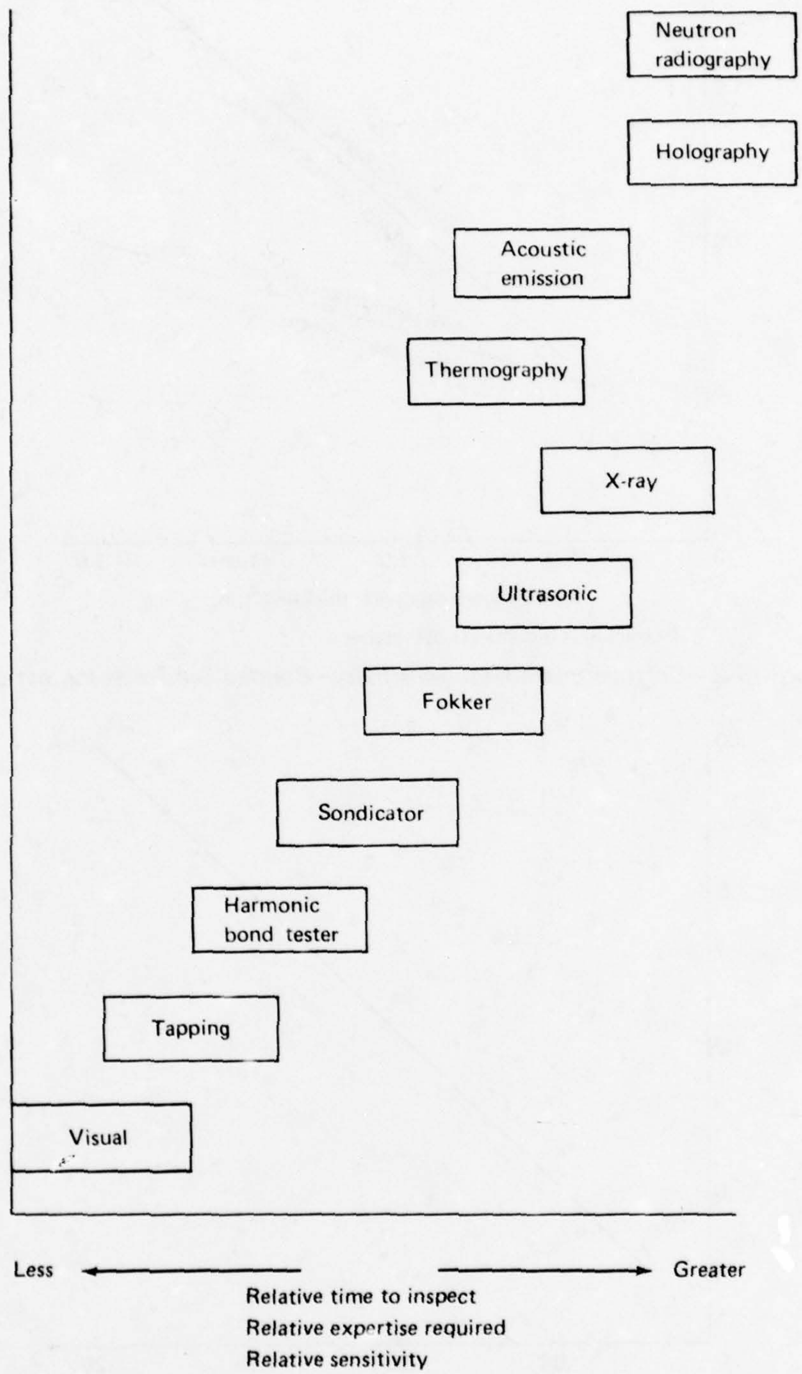


Figure 10-4.–General Comparison of Inspection Techniques

10.2.2 VISUAL

Nondestructive inspection by visual means is by far the oldest and most economical method. Consequently, visual inspection is performed routinely for damage assessment and at all stages of repair. In some instances visual aids such as microscopes, borescopes, magnifying glasses, and other optical devices are used to inspect areas for defects that are either inaccessible or cannot be seen with the unaided eye. See figure 10-5 for an example of visual inspection with the aid of a flashlight and the correct angle of vision.

10.2.3 TAPPING

Tapping inspection (fig. 10-6) is a nondestructive method for detection of voids or delamination in bonded areas. When tapping any area using a tapping hammer (fig. 10-7), coin, or other suitable object, a ringing sound is produced. The tapping rate is accomplished to produce a continuous sound so that any difference in sound tone can be detected by a trained ear. This inspection should be conducted in a relatively quiet area.

10.2.4 ULTRASONIC

Ultrasonic inspection has proven to be very useful for detecting internal delaminations, voids, and inconsistencies in bonded structure. The method uses sound waves with a frequency above the audible range. The waves are induced into the part by a piezoelectric transducer transmitter. This sonic energy travels through the part, and any marked change in acoustic properties of the material will affect the sound traveling to a receiving transducer.

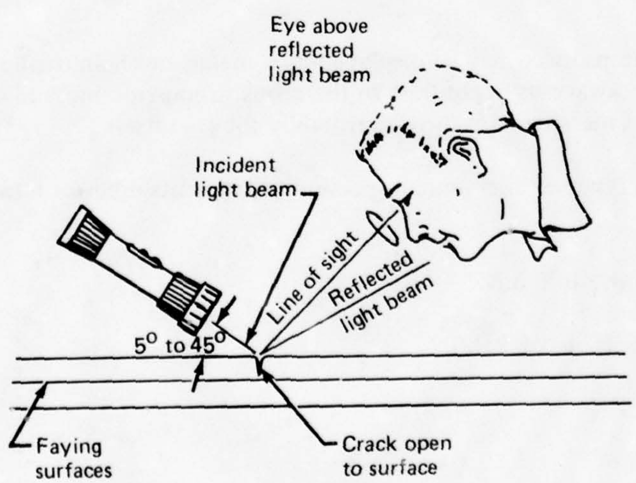


Figure 10-5.—Visual Inspection of Metal Surface

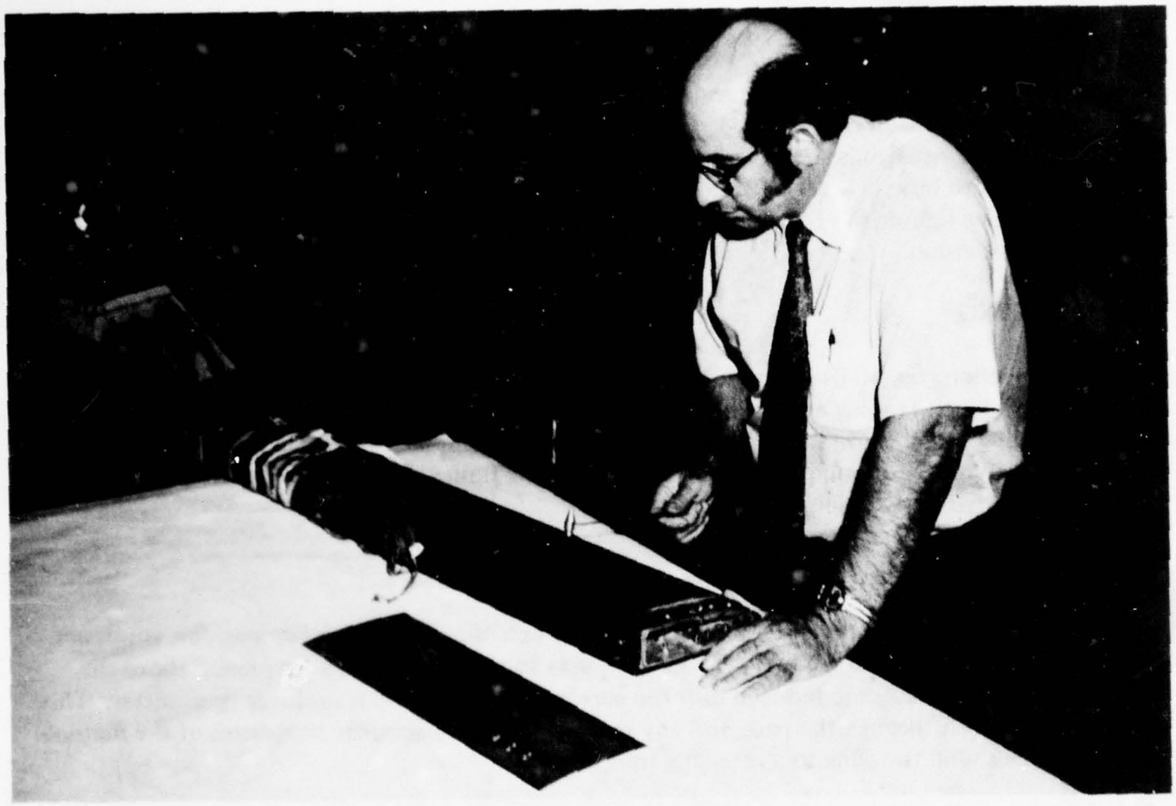
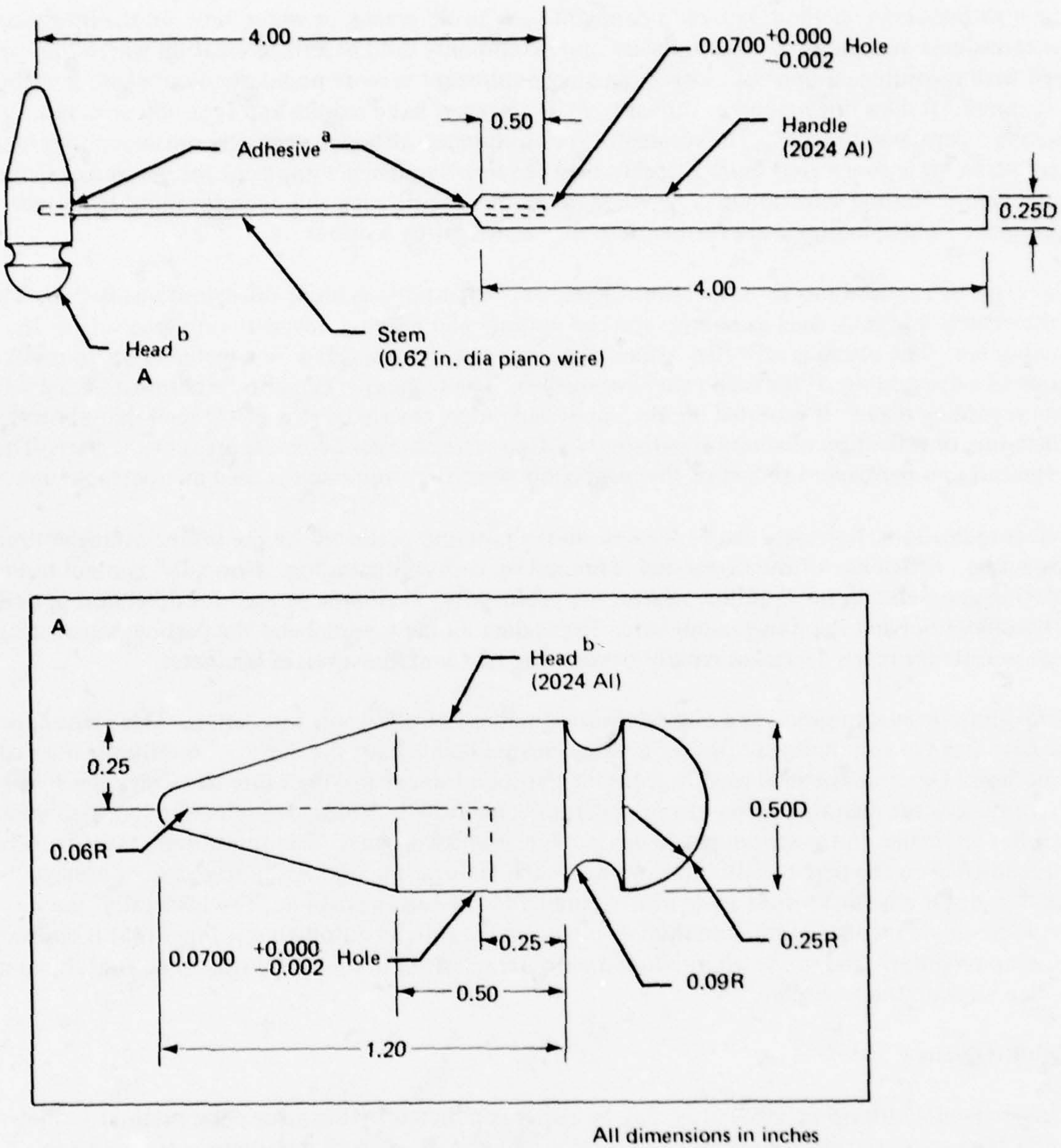


Figure 10-6. – Tap-Testing Honeycomb Panel

The information to the transducer may be displayed by a meter, or on an oscilloscope or chart. (Note: This use of induced sound waves is in contrast to the acoustic emission method described in sec. 10.2.9 in which the sound waves measured are those emitted by the part itself.)

There are basically three types of ultrasonic inspection instruments used for bond testing. These are as follows:

- High frequency (1 mHz to 5 mHz)
- Low frequency (15 kHz to 50 kHz)
- Resonance



[a] Liquid/paste adhesive may be used if desired. Hole in handle/head may be reduced to provide an interference fit and preclude the need for the adhesive.

[b] 125/ All machined surfaces, ref MIL-STD-10

Figure 10-7.—Inspection Tap-Hammer Details

The high frequency method requires a couplant such as oil, grease, or water between the interface of the transducer and the part. The units are quite commonly used at a fixed location where they are used with recording equipment. Low frequency equipment is more popularly used where portability is required. It does not require a couplant. It is, however, less accurate and typically does not provide a permanent record. The resonant-type equipment, although generally portable, does require a couplant. It is considered more accurate than the low frequency equipment for inspecting laminated metal areas. Method selection may be made on required sensitivity and operator familiarity and preference. These methods are further described in following sections.

There are two procedures for inspection. These are either pulse echo or through-transmission. The pulse echo is normally used as a single contact method and requires access to only one side of the component. The sound is reflected off a surface and may be displayed on a meter or on an oscilloscope as a discrete signal for each reflective surface. The technique can also be automated and a C-scan recording made. It is usable on most materials where the signal strength is such that absorption, scattering, or reflection of sound significantly differs over good or defective areas of the part. There is typically no permanent record of the inspection when the equipment is used as a portable unit.

Defect indications, however, can be marked on the part and evaluated by the inspector at the time of inspection. Efficiency of the inspection is limited by part configuration. Normally, contact inspection will find anomalies in the bondline nearest the probe only. It cannot be used for detection of defects in bondlines beyond the honeycomb core. Depending on the material and the particular instrument type, sensitivity often decreases rapidly beyond the first bondline even in laminates.

Through-transmission provides a more definitive method of ultrasonic inspection. This procedure has the advantage of responding to discontinuities located throughout the depth of multilayer bonded structures. One transducer is used to transmit the sound waves and the other to receive the signal after it passes through the region of the structure being tested. Voids, delamination, crushed core, or other anomalies in the structure attenuate the transmitted signal. The transducers must be aligned perpendicular to the part to assure maximum available ultrasonic signals. In the case of honeycomb, the transducer alignment must be as nearly parallel to the cell as possible. The inspection can be conducted by a manual contact method or incorporated into an automated scanner that is coupled to a C-scan recorder. The sound attenuation due to irregularities in the structure can accurately be traced in plan view on the recording.

High Frequency

High frequency ultrasonic inspection may be either conducted by the pulse echo method as shown in figure 10-8 or by through-transmission shown in figure 10-9. Several instruments are available. Examples include the Immerscope, Reflectoscope, Krautkramer, Magneflux, etc.

The through-transmission procedure is quite commonly used for best defect definition (see fig. 10-1 and 10-2). The main disadvantages of this method are that it is time-consuming and lacks portability. Other limitations are that the couplant (water or oil) must not damage the part, access to opposite surfaces is required, a continuous path must be available to conduct sound through the part, and the depth of a flaw is not determinable if more than one bondline is present. In spite of these problems, through-transmission ultrasonic remains one of the most reliable and sensitive methods for inspecting adhesive-bonded components.

Through-transmission inspection can be conducted by immersing the part in water or by the use of a water column as shown in figure 10-10. In using the water column, there must be no water bubbles between the transducer and the part as this will cause false indications of defects.

The through-transmission method can conveniently be set up to automatically scan the part and produce a plan view record as shown in figure 10-11. The record indicates the relative intensity of the signal through the part. The setup may be a go/no-go type recording or indicate levels of intensity. This latter may be accomplished with a multicolor recording head, as shown in figure 10-12, or a computerized method may be used where the printout is a variable number or darkness, as shown previously in figure 10-11.

The scanning rates are in the vicinity of 6 in./sec for the black-and-white recording and 1 in./sec for the multicolor. The latter is slower because of the response time of the multiple recording pens. An increased coverage rate may be obtained by use of multihead transmitter/receiver units and computerized methods.

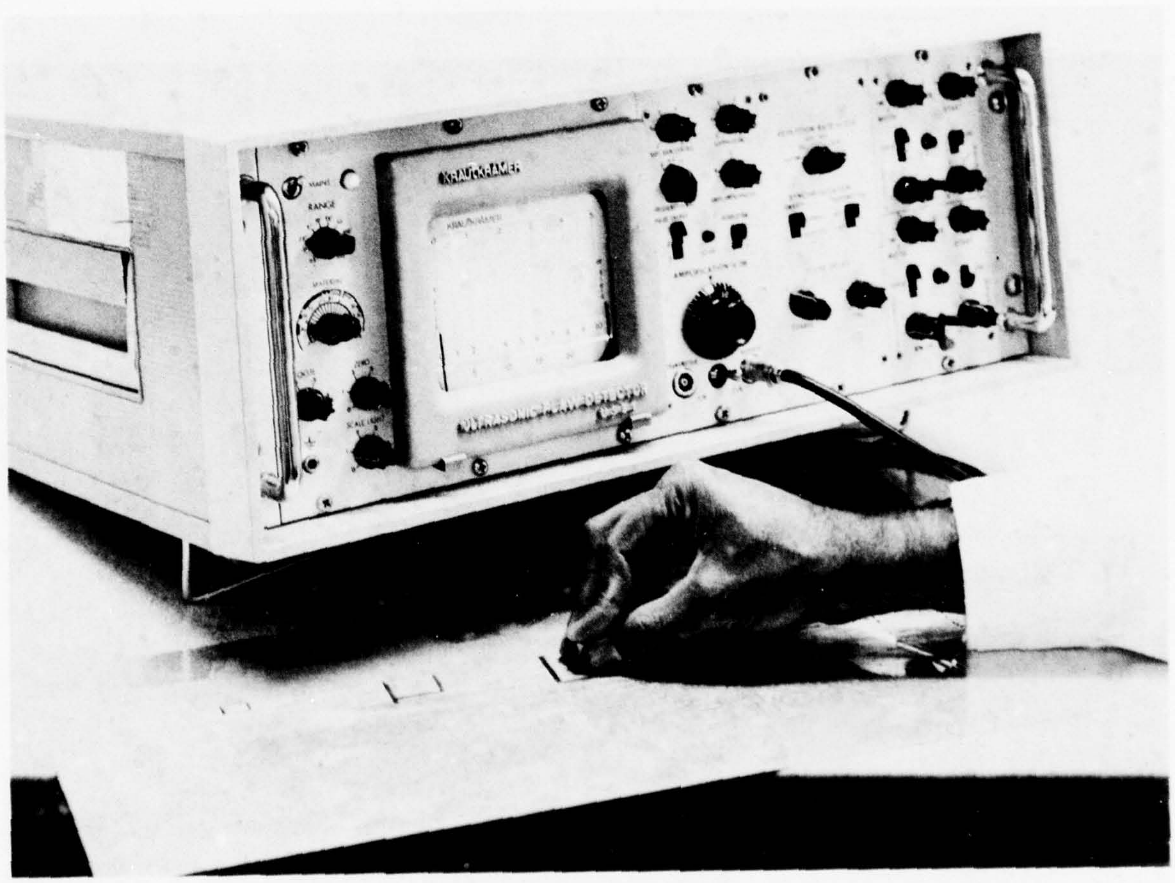


Figure 10-8.—Operation of Pulse Echo Unit on Multilaminate Standard

Defect detection sensitivity is quite dependent on the water jet diameter and the width of the scanning index. Typical jet diameters range from 3/16 to 1/4 inch. Traverse or scan widths are typically 0.030 to 0.040 inch for black and white and 0.070 to 0.080 inch for color. The scan width should be adjusted to 1/3 to 1/4 of the void size to be detected.

Low Frequency

Low-frequency inspection units (15 to 50 kHz) have been developed especially for honeycomb bonded structure. Their main advantages are portability and the fact that they do not need a liquid or gelatin couplant between the part and transducer. Some degree of detection sensitivity is sacrificed over that of the high frequency through-transmission units, as indicated in figures 10-1 and 10-2.

Harmonic Bond Tester. The Harmonic Bond Tester (fig. 10-13) is a portable low-frequency instrument using a single transducer for inspection of metal laminations and metal-to-honeycomb bonded structures. The inspection is performed by the use of a coil which electromagnetically vibrates the

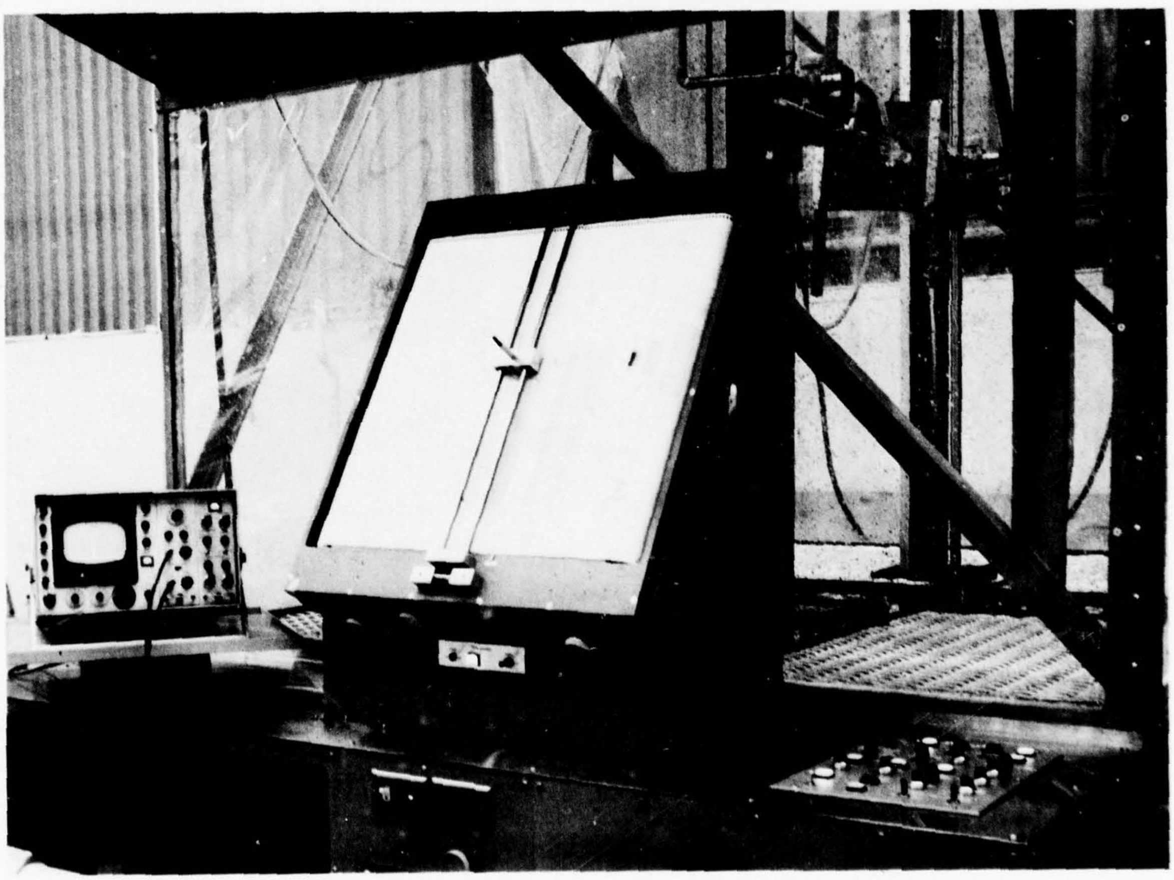


Figure 10-9. –Water-Coupled Ultrasonic Through-Transmission Unit

metal face sheet of a laminate or honeycomb structure. It then measures the acoustical response of this vibrating face. The coil operates at approximately 15 kHz, and its electromagnetic field vibrates the face sheet at twice the coil frequency. The face sheet vibrations create sound waves which are air coupled to a microphone located above the electromagnetic coil in the probe. The amplitude of the acoustic response is indicated by a meter. The degree of the acoustic amplitude is directly related to the face sheet movement or disbond. Generally, the response from a part being inspected is compared to a previously prepared standard representing acceptable and rejectable areas.

The Harmonic Bond Tester is suitable for rapid manual checks of the repaired areas. The probe size (approximately 1-1/4 inches in diameter by 1-1/2 inches high) limits access to the area next to the vertical sections of hats or tees. The skin next to the probe must have good electrical conductivity, hence, it is most ideal for aluminum face sheet structures. The instrument sensitivity for void detection decreases rapidly for skin thicknesses over 0.060 inch and near the edges of the part.

Sondicator.—The Sondicator (fig. 10-14) is a pulsed transmit/receive ultrasonic portable instrument that is capable of operating in a very low acoustic frequency range, 25 to 50 kHz. The instrument operates within this range at a single frequency. This is selected by manual tuning for best instrument performance. The instrument is used primarily to detect delaminations of laminar-type voids

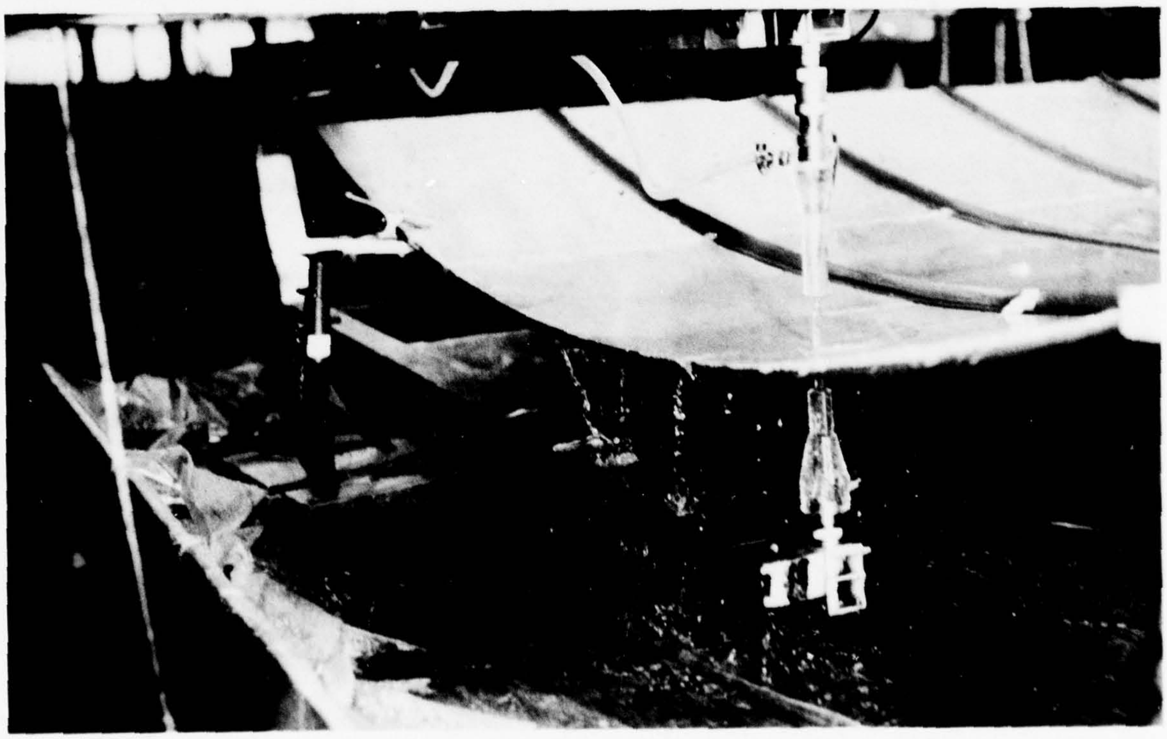


Figure 10-10.—Through-Transmission Inspection Using Water Column as Coupling Agent

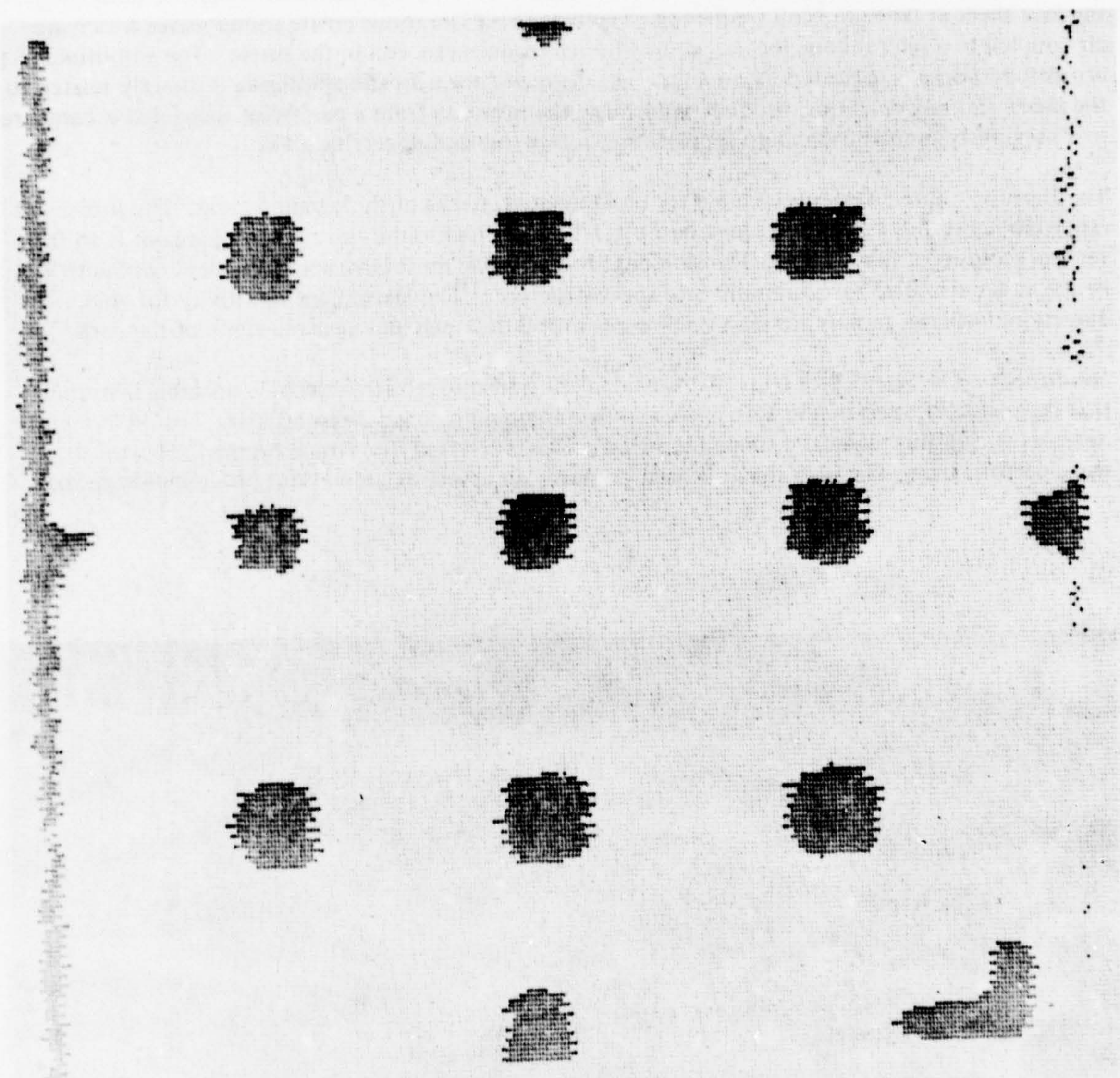


Figure 10-11.—Planform Print-Out Made by Through-Transmission Unit Showing Voids in Bonded Demonstration Panel

in both nonmetal and metal structures. The inspection may be performed from one face of the structure (fig. 10-14) or by through-transmission (fig. 10-15).

The Sondicator transmits a short pulse of sound into a part and then receives the sound after it has traveled some distance through the part. During this travel, changes in the part's structure cause changes in the amplitude and/or phase (i.e., time shift) of the received sound. The Sondicator detects these changes in such a manner that the inspector can translate them into the corresponding changes in the structure. In manual application, the instrument has limited access to areas next to the vertical section of a tee and hat, as limited by the size of the probe (approximately 1-1/4 inches in diameter and 1-1/2 inches high). Multiple bondlines and part edges will reduce the sensitivity of the instrument. The instrument probe is generally in contact with the part surface when inspecting from one side only. When used in this mode the condition of the surface, such as fiberglass roughness or perforated

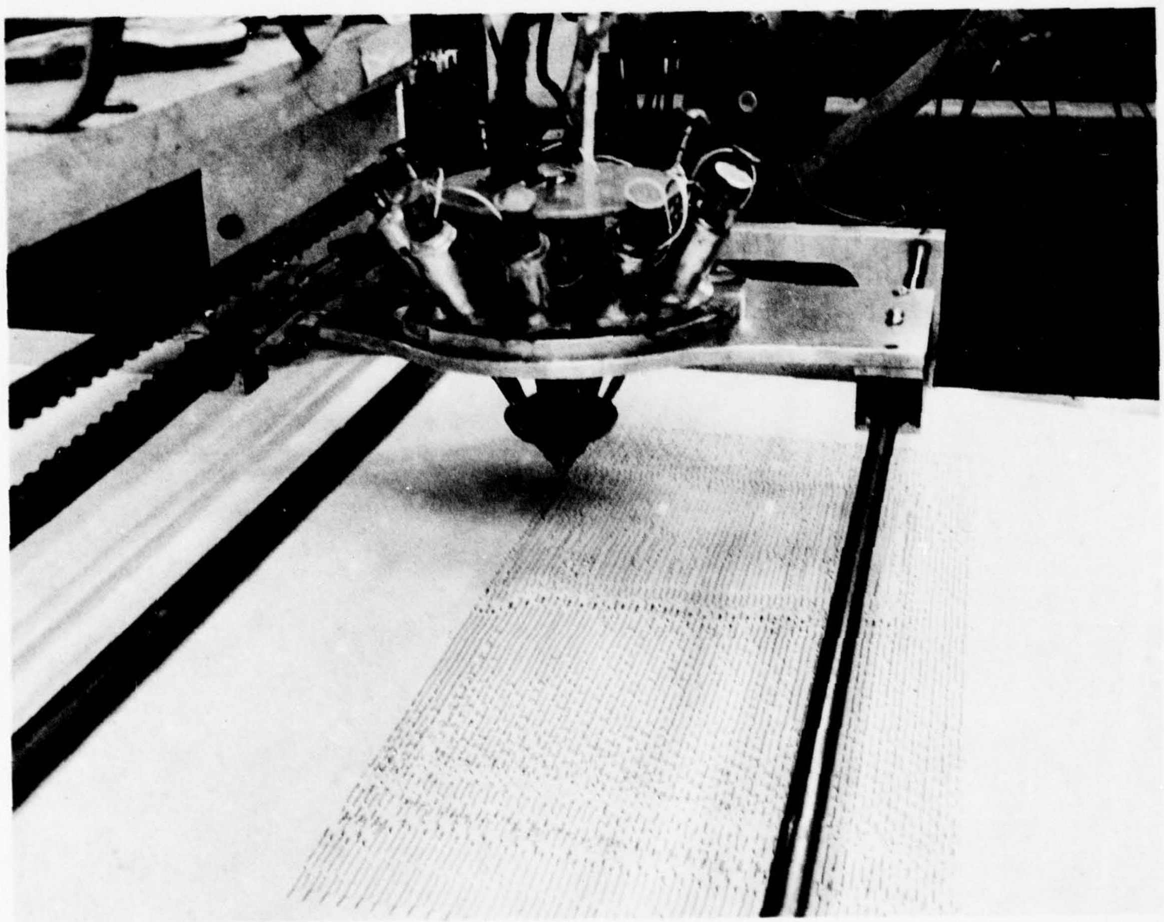


Figure 10-12.—Through-Transmission Unit Printer Using Multicolor Recording

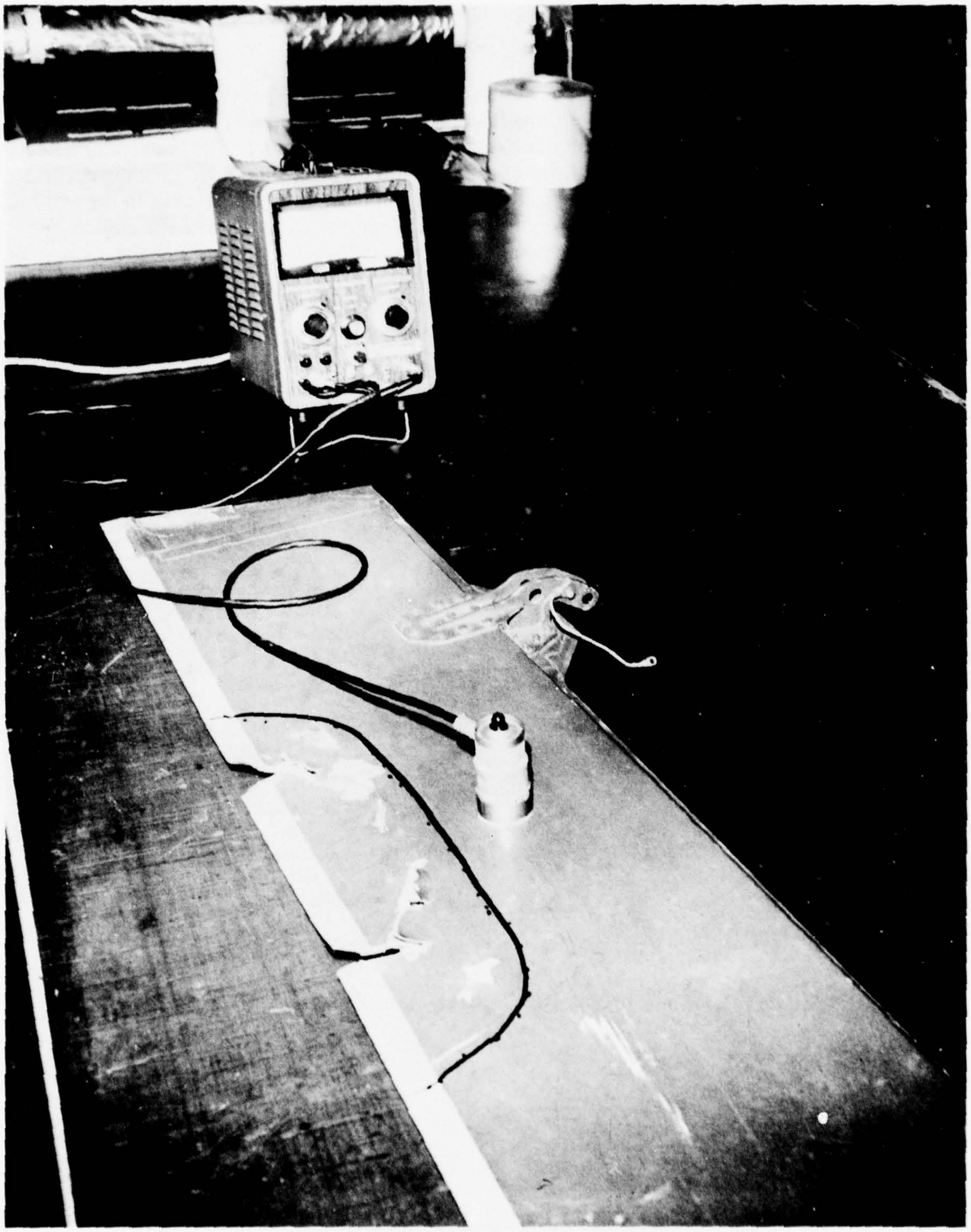


Figure 10-13.—Harmonic Bondtester Being Used to Inspect Honeycomb Component

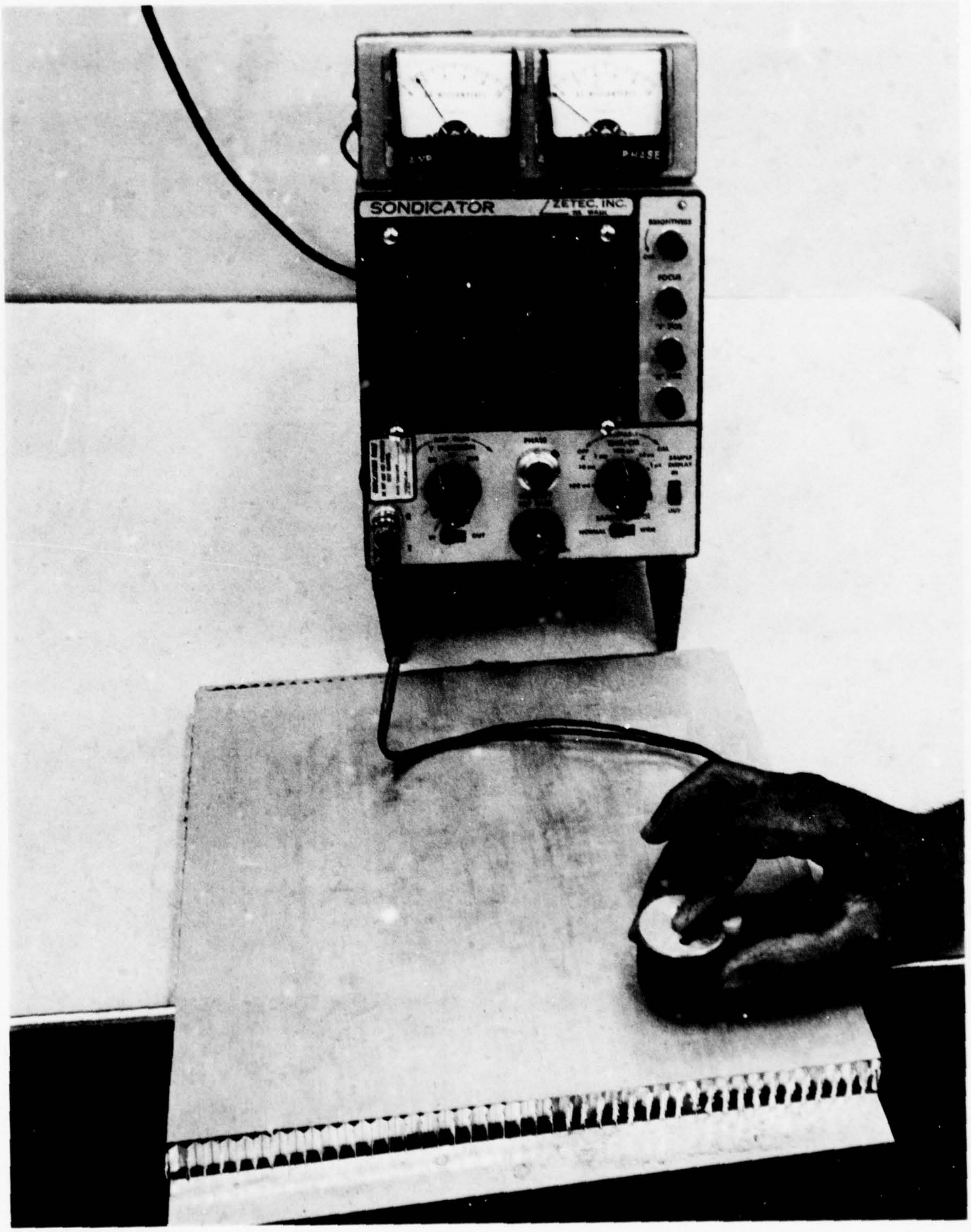


Figure 10-14.—The Sondicator Being Used to Inspect Honeycomb Panel From One Side

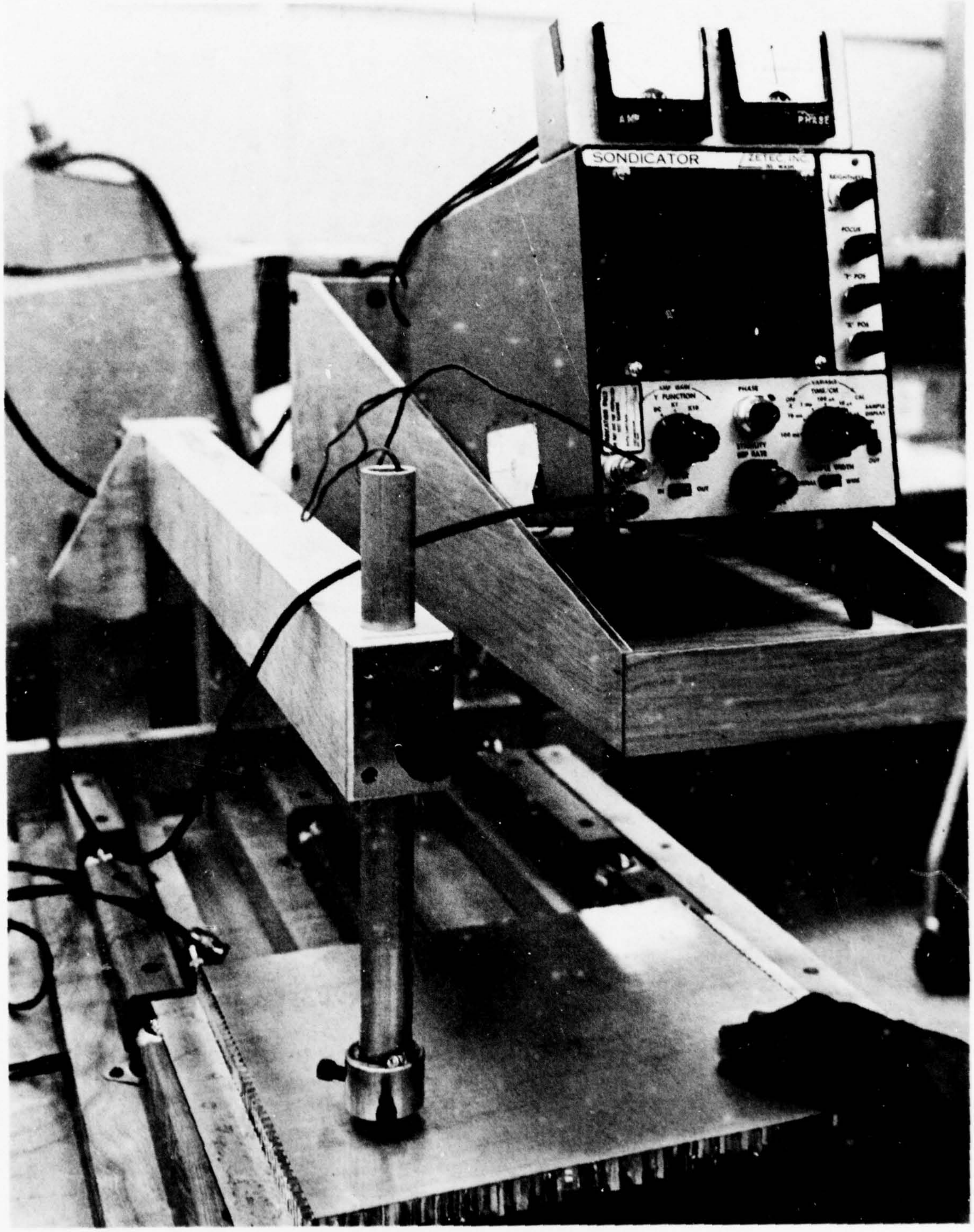


Figure 10-15.—The Sondicator Being Used to Inspect Honeycomb Panel by Through-Transmission

acoustic surfaces, may affect the reading and give false indications. Surface contact causes wear on the probe tips. These should be examined frequently to assure they have not worn to a point where instrument sensitivity is affected. Sensitivity may be validated by inspection of a standard test panel.

Resonance Type

Fokker Bond Tester.—The Fokker Bond Tester (fig. 10-16) is a portable instrument that operates by a transducer resonant method. The system is a combination of ultrasonic and physical vibrating techniques. The Fokker instrument consists of two basic elements. The bulk of the instrument, or its first element, contains the power plant and the driving mechanism as well as the readout scales.

The second element is the transducer or probe, which is made to vibrate at resonant frequency.

The instrument requires a couplant medium such as a light oil or glycerine mixture. The necessity for the removal of the couplant after inspection is a disadvantage.

The Fokker Bond Tester is especially adaptable to the inspection of bonded metal laminates. It is more sensitive for this application than the low-frequency instruments described in section 10.2.4. The instrument may discriminate between voids in multiple bondlines. The sensitivity decreases below the first bondline, especially in the case of heavy structures. In practice, the instrument is standardized on a face sheet or sheets of the same thickness as those in the bondlines to be inspected. A zero reading is obtained on the standard. When the instrument, thus adjusted, is applied to the bonded joint, a shift in frequency and a change in amplitude are obtained that relate to the quality of the bond. In use, the transducer must be positively positioned as the reading is obtained. It is then repositioned for the next reading. In this manner a defect may be plotted or outlined. On multiple metal-to-metal bondlines, the inspection should be conducted from the side of the thinnest outside adherend (fig. 10-17). Contact must be continuous between the probe and the adherend (no bubbles). This instrument is not always sensitive on honeycomb assemblies, therefore it should be used only if successful in detecting voids in the standard.

10.2.5 RADIOGRAPHY

Radiography is a very useful NDI method in that it essentially allows a view into the interior of the part. Portable equipment is available, and in some instances inspection can be done without removing the part from the aircraft. In most cases, however, the part is taken to the X-ray laboratory. This more readily allows access to both sides of the part and allows the part to be placed in a position where it can best be inspected for a particular defect.

The technique provides the advantage of a permanent film record. On the other hand, it is relatively expensive, and special precautions must be taken because of the potential radiation hazard. When inspecting with a radiographic method, use trained personnel and verification standards. Conduct a daily check of the film-developing solutions. Do not bypass radiation safety requirements or attempt to reduce inspection time by increasing the kilovoltage.

Conventional Radiography

This inspection method utilizes a source of X-rays or gamma rays to detect discontinuities or defects through differential densities in the material. A typical radiographic exposure setup is shown in

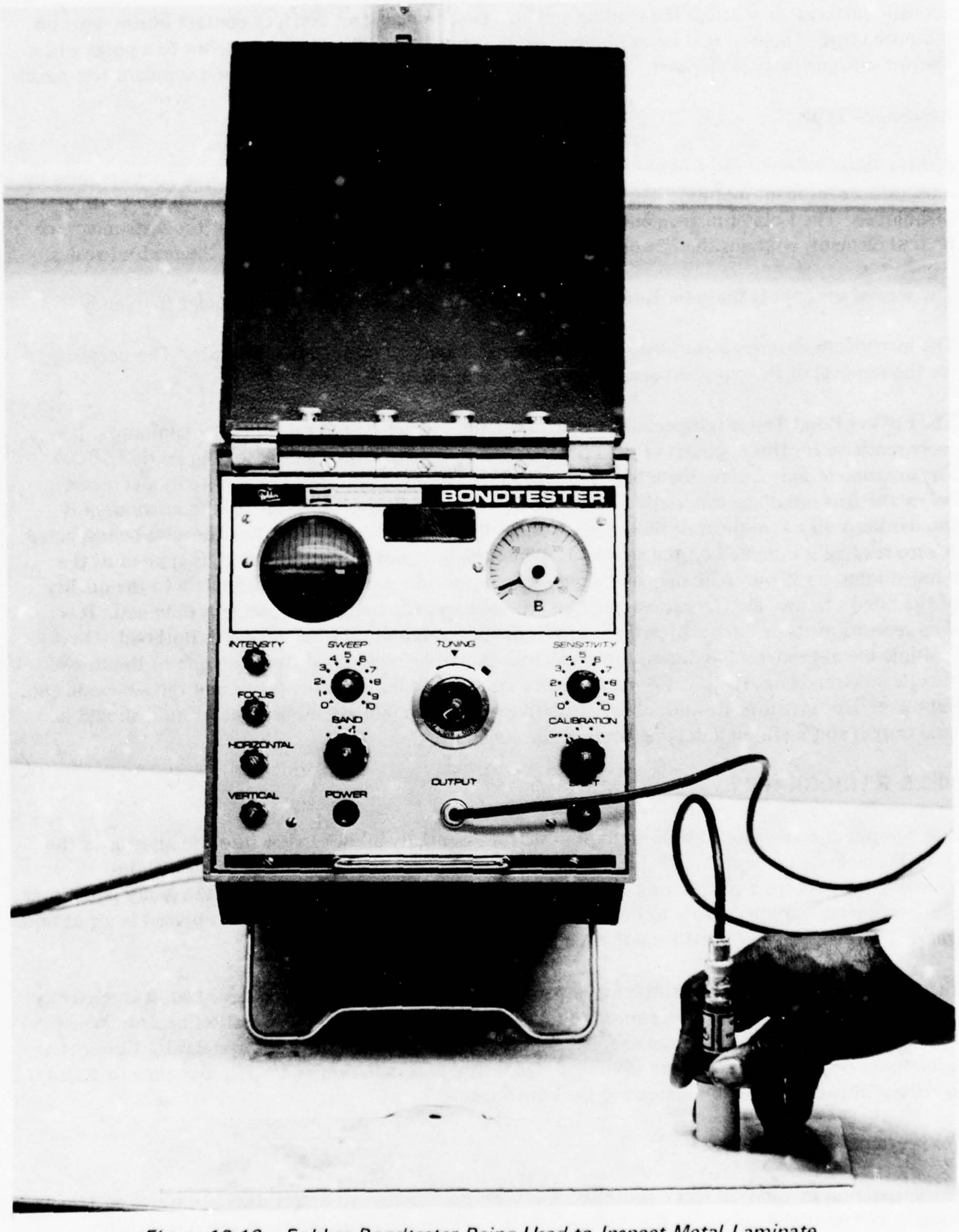


Figure 10-16.—Fokker Bondtester Being Used to Inspect Metal Laminate

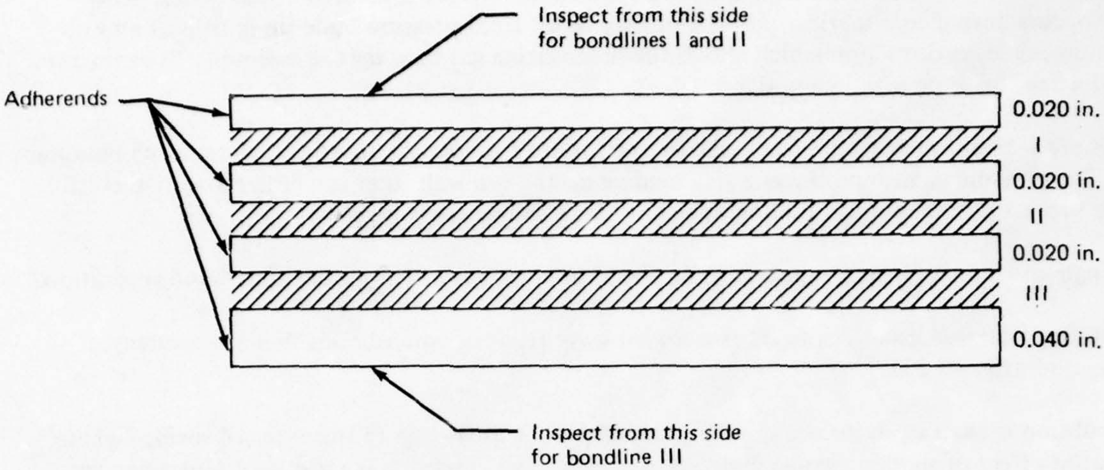


Figure 10-17.—Proper Fokker-Bondtester Inspection Procedure for Multiple Metal Laminate Bondlines

figure 10-18. Variations in density over the part area are recorded by various degrees of exposure of the films. A standard (penetrameter) having various degrees of density is used in the scene to indicate that proper exposure and resolution have been obtained.

Since the method records changes in total density through the thickness, it is not a preferred method for detecting defects such as delaminations that are in a plane normal to the ray direction. It is the most effective method, however, for detecting the presence of water in honeycomb core cells. It is also very effective in identifying core that has been dislocated or damaged or voids in bondlines parallel to the ray direction. Various types of defects that are detected by X-ray are as follows:

Water in Core Cells.—Water in core may be detected radiographically when the cells are filled to as little as 10 percent of the core height. Detection sensitivity is dependent on the sandwich skin thickness and radiographic technique. A problem may occur in the ability to determine whether the suspect area indicates excess adhesive, filler, or water. Water images usually have the same film density from cell wall to cell wall, while adhesive or filler images may vary in film density within the cell or show indications of porosity. A radiograph of moisture in honeycomb is shown in figure 10-19.

Crushed Core.—This condition may be associated with a dent in the skin. Crushing of the core greatly diminishes its ability to support the face sheets. A radiograph indicating crushed core is shown in figure 10-20.

Condensed Core.—This condition occurs when the edge of the core is compressed laterally. This may result from bumping the edge of the cure during handling or slippage of details during bonding. Figure 10-21 shows core that has been condensed by excess expansion of the adhesive at a core-to-fitting splice.

Node Separation.—This condition results when the foil ribbons are separated at the nodes. This usually occurs during core fabrication. It also may result from pressure build-up in cells as a result of vacuum bag leaks or failure, which allows the pressurizing gas to enter the assembly. A radiograph of a failure of this type is shown in figure 10-22.

Blown Core.—This occurs after a bag break or as a result of sudden change of pressure in the bonding cycle. The pressure change produces a side loading on the cell walls that can either distort the cell walls or break the node bonds. Radiographically this is indicated as follows:

- Single cell damage usually appears to be round or elliptical with a partial node-bond separation.
- Multicell damage usually appears as a curved wave front of core ribbons that are condensed together (fig. 10-23).

The condition is most likely to occur at the part edge in an area close to the external surface where the greatest effect of sudden change in pressure occurs. The condition is most prevalent wherever there are leak paths such as gaps in the closure ribs to accommodate fasteners, or chemically milled steps in the skin where the core may not fit properly. When associated with skin-to-core unbonds, the condition is detectable by pulse-echo and through-transmission ultrasonic techniques. The condition is very readily detected by radiography when the X-ray beam centerline is parallel to the core cell walls.

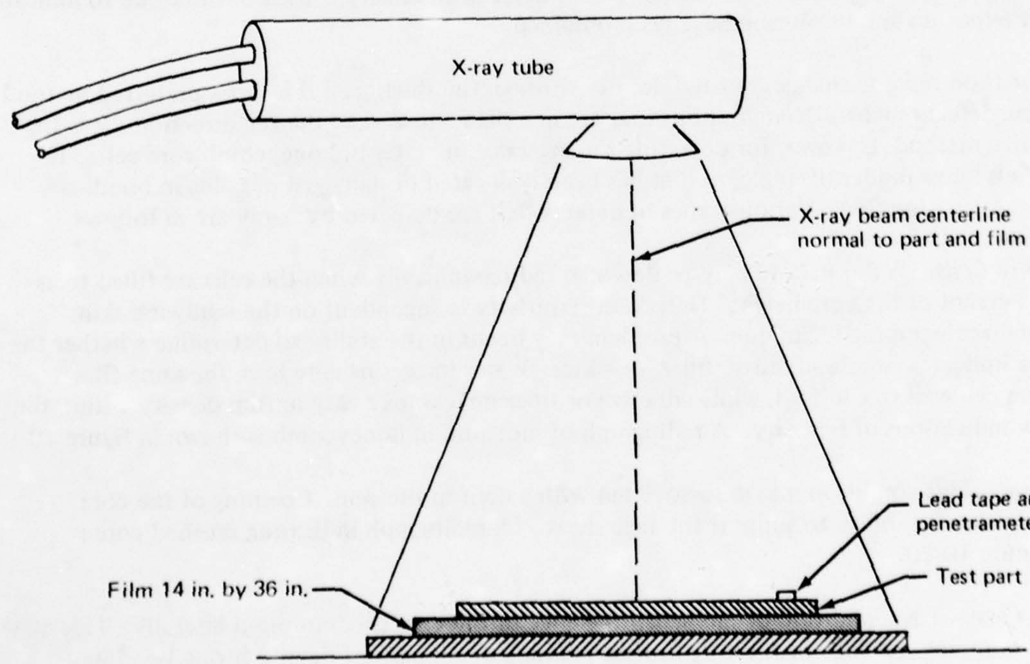


Figure 10-18.—Typical Radiograph Exposure Setup

Voids in Foam Adhesive Joints.—Flaws in core-to-core or core-to-fitting foam joints can result from several conditions. Radiography is an effective means of detecting many of these.

- The foam adhesive can slump or fall leaving a void at the top surface (fig. 10-24). This particular condition is most readily detected by ultrasonics.
- The core may be cut too small and the foam does not expand uniformly to fill the excess area. This condition is clearly depicted by the radiograph in figure 10-25.
- The foaming adhesive can fail to expand and surround the core tangs. This is illustrated in the radiograph in figure 10-26.

Low Voltage Radiography (25 to 50 kV)

The use of conventional X-ray techniques is, in general, limited to the inspection of the metal details in the bonded assembly and the adhesive core splice material. The adhesive layer between the metal faying surfaces, or between the faces and the core, most commonly is a thin layer. This, in combination with the adhesive's typical low density, causes it to be relatively X-ray transparent.'

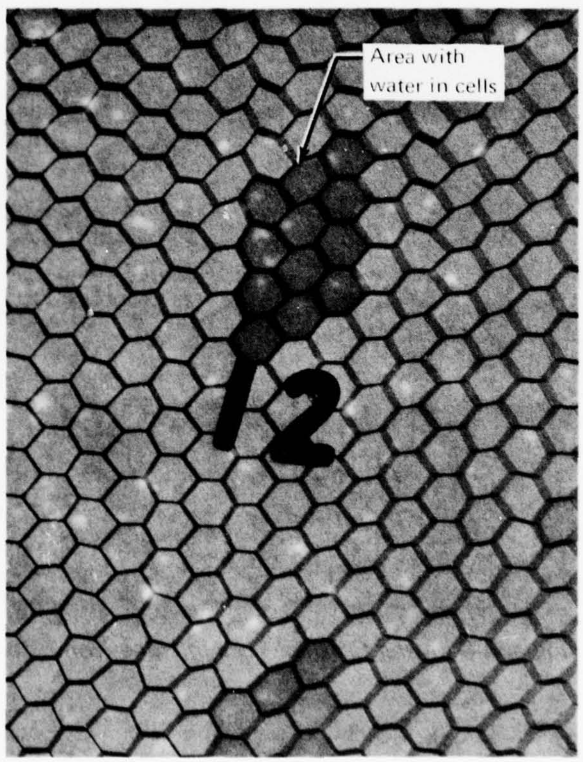


Figure 10-19.—Radiographic Inspection Showing Water in Honeycomb Core Cells

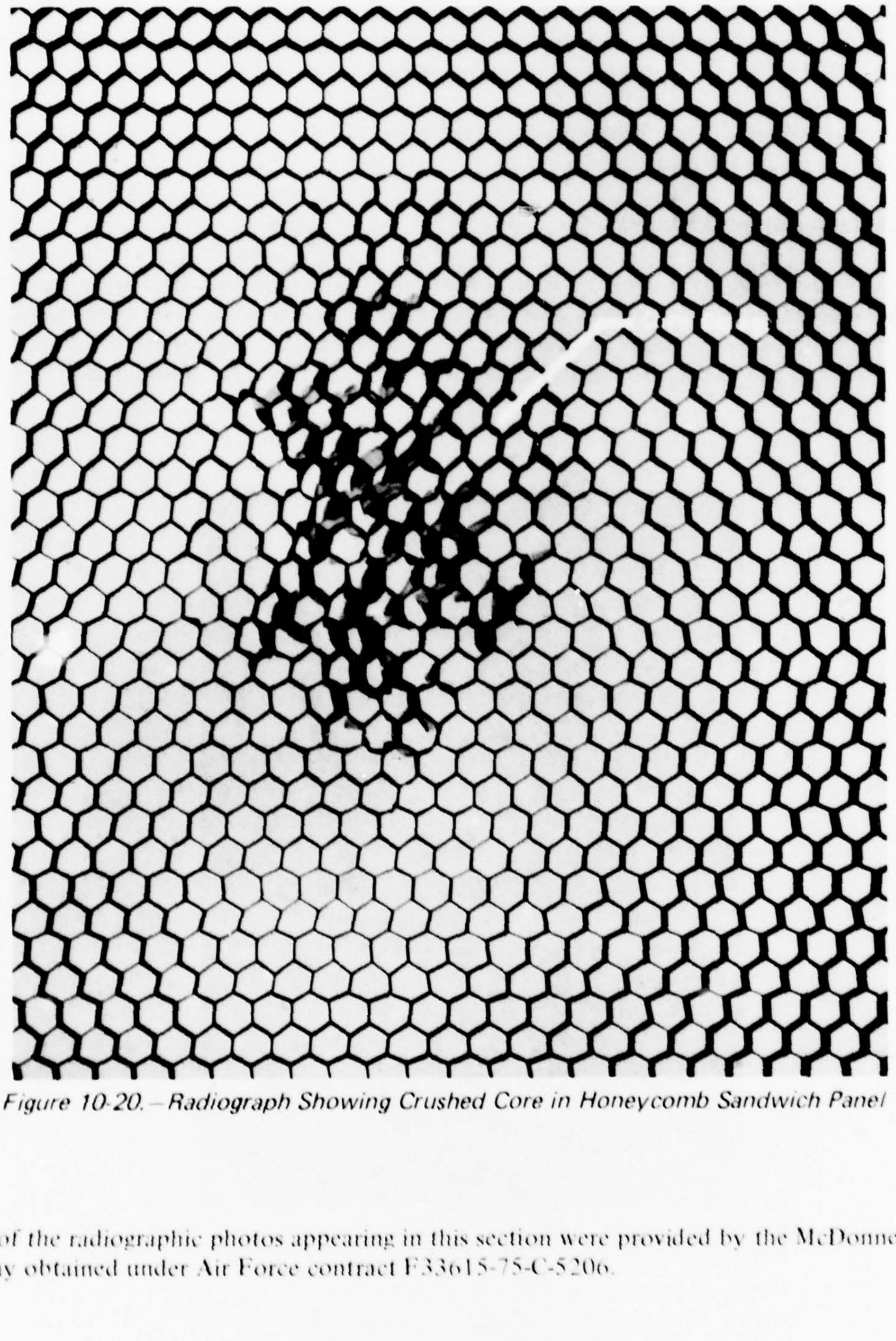


Figure 10-20.—Radiograph Showing Crushed Core in Honeycomb Sandwich Panel

Several of the radiographic photos appearing in this section were provided by the McDonnell Aircraft Company obtained under Air Force contract F33615-75-C-5206.

In some cases, however, dense adhesives are used, and X-ray techniques can be employed to inspect the bondline. This greatly increases the degree of inspection that can be accomplished. Adhesives of this type are usually of a high temperature variety that contain a filler such as aluminum powder. An example of this is the FM400 adhesive marketed by American Cyanamid and used on the F-15.

Considerable work has been done on bondline inspection techniques and in the development of accompanying inspection standards (ref. 1). Other than a dense adhesive, additional items that are important in accomplishing effective bondline inspection are:

- A low X-ray kV
- High-contrast film
- An experienced machine operator and film interpretor

Examples of types of defects that can be successfully detected in filled adhesives using proper procedures are as follows:

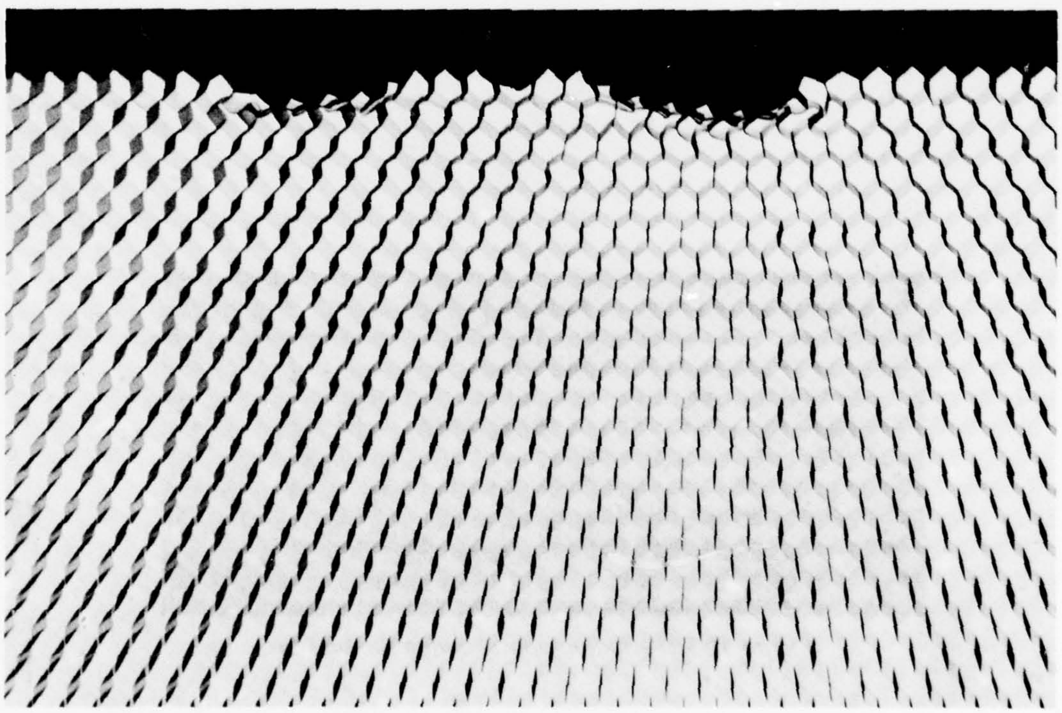


Figure 10-21.—Radiograph of Locations Where Core-to-Fitting Splice Adhesive Has Over-Expanded and Condensed Core

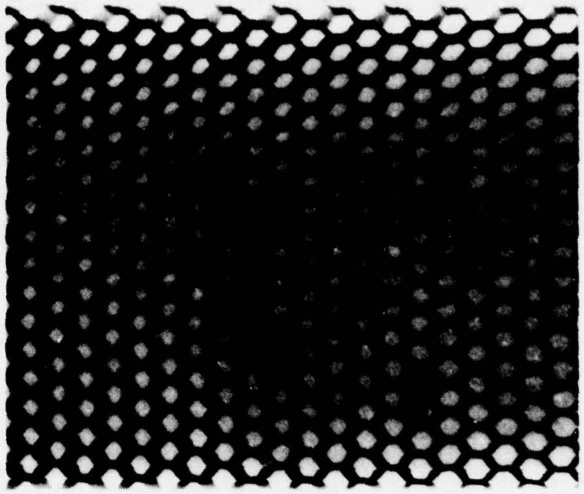


Figure 10-22.—Radiograph Showing Separation of Honeycomb Node Bonds

Figure 10-23.—Radiograph Showing Blown Core

Metal-to-Metal-Flaws.—Disbonds of this type can occur when the core is slightly higher than a closure member, lack of pressure in tooling, or by air trapped in the adhesive prior to cure. Providing the above requirements are met, this type flaws are readily detectable by low kilovoltage X-ray techniques (see fig. 10-27). If the flaw is the result of insufficient pressure, the adhesive will be porous, as indicated by dark spots. The lower the kilovoltage and/or the thicker or denser the adhesive, the higher the resolution of the flaw image. It is claimed that, in general, the flaw size detectable by radiography is smaller than that detected by ultrasonics.

Skin-to-Core Voids at Edges of Chemically Milled Steps or Doublers.—This condition occurs when the adhesive bridges or forms a gap at the edges of chemically milled or laminated steps or doublers, as shown in figure 10-28. This is detectable radiographically as a dark line or an elliptically shaped dark image.

Missing Fillets.—As pressure is applied during the bonding cycle, adhesive fillets are formed at the edges of each honeycomb cell. If pressure is not maintained properly or the adhesive is outdated, weak or no fillets will be formed. This condition is readily detected by X-ray by directing the radiation at an angle of approximately 30° to 45° with respect to the centerline of the core or closure web. The fillets appear radiographically as dark semicircles or hexagons in a gray matrix with the cell walls forming vertical intersecting white lines. Lack of fillets is indicated by the lack of semicircles or hexagons (fig. 10-29 and 10-30).

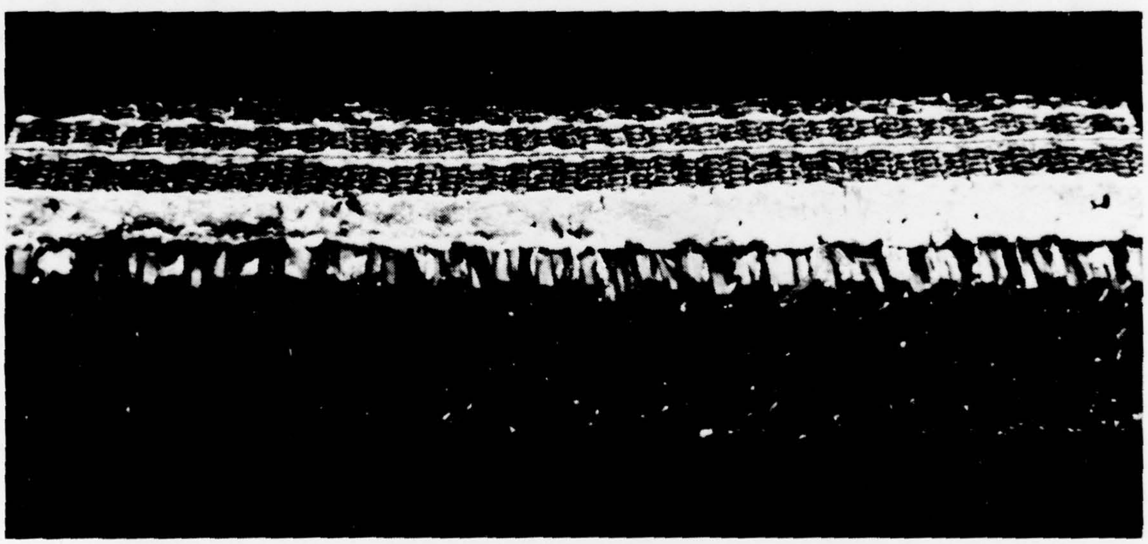


Figure 10-24.— Failure of Foaming Adhesive to Fill Core-Splice Joint

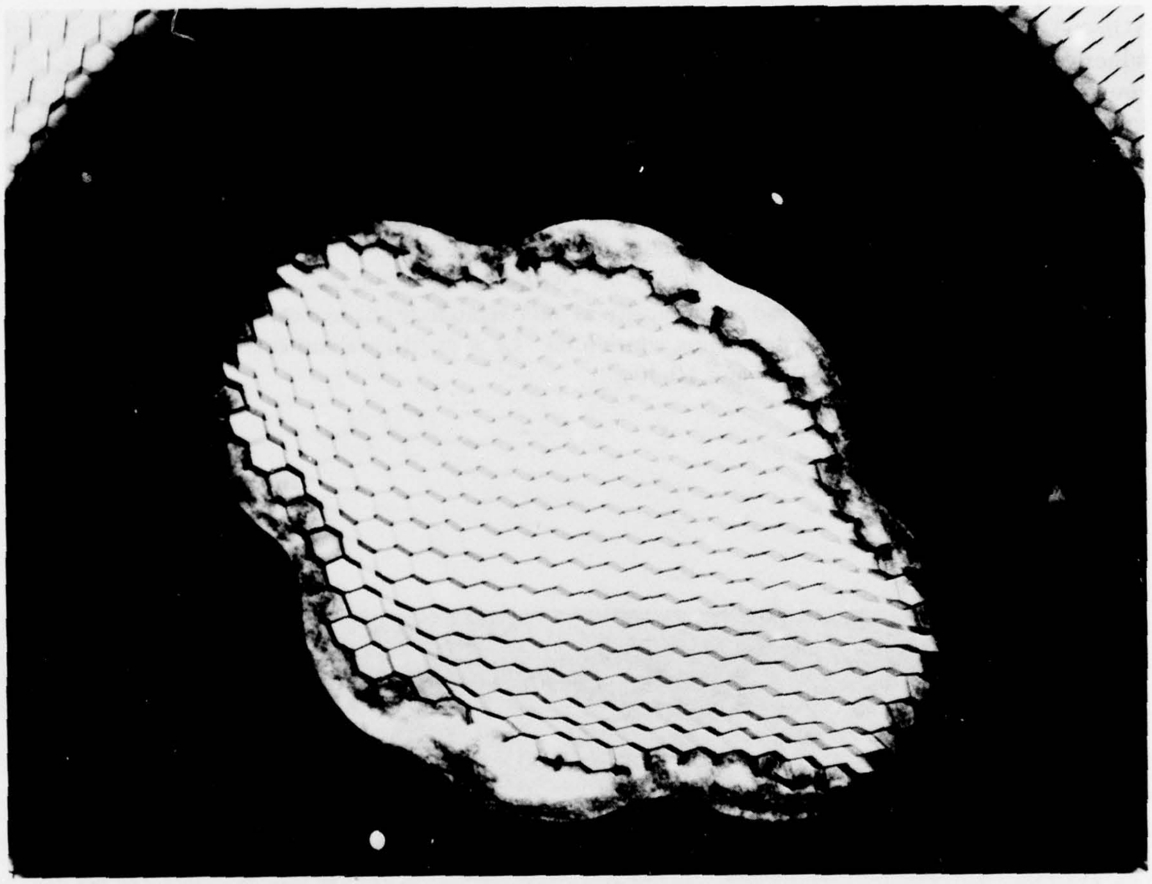


Figure 10-25.—Radiograph Showing Area Where Foam Failed to Fill Void Between Fitting and Core

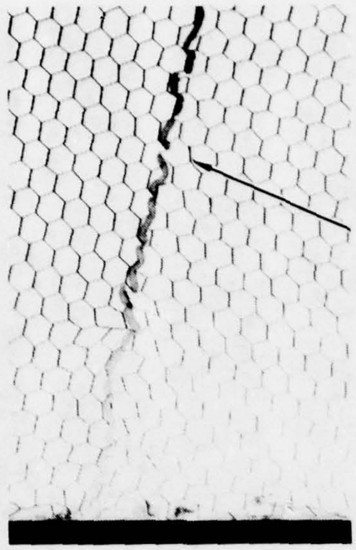


Figure 10-26.—Radiograph of Failure of Foam Adhesive to Expand into Adjacent Cells

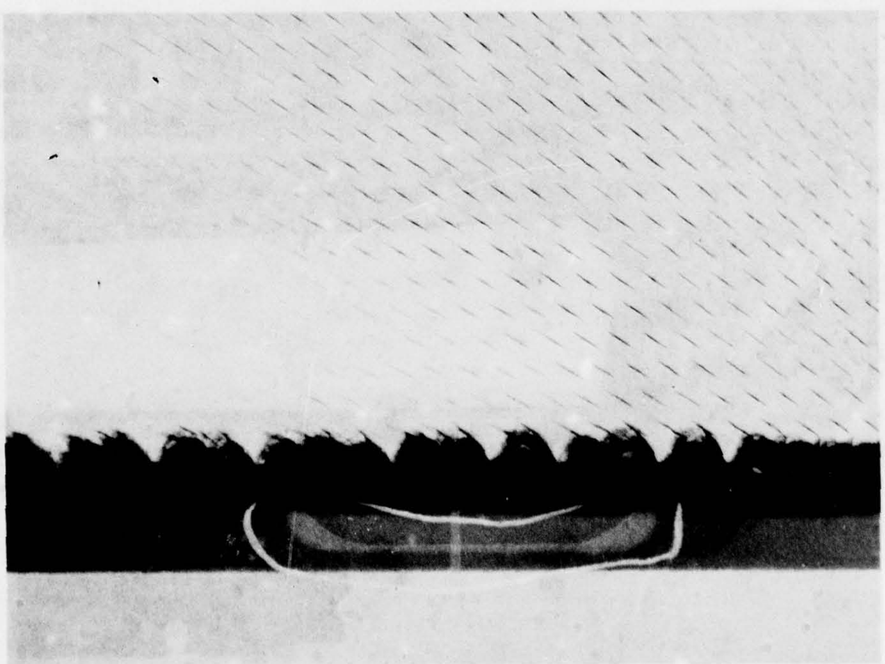


Figure 10-27.—Radiograph of Flaw in Adhesive Bondline

Figure 10-28.—Void at End of Doubler Due to Improper Core Fit-Up

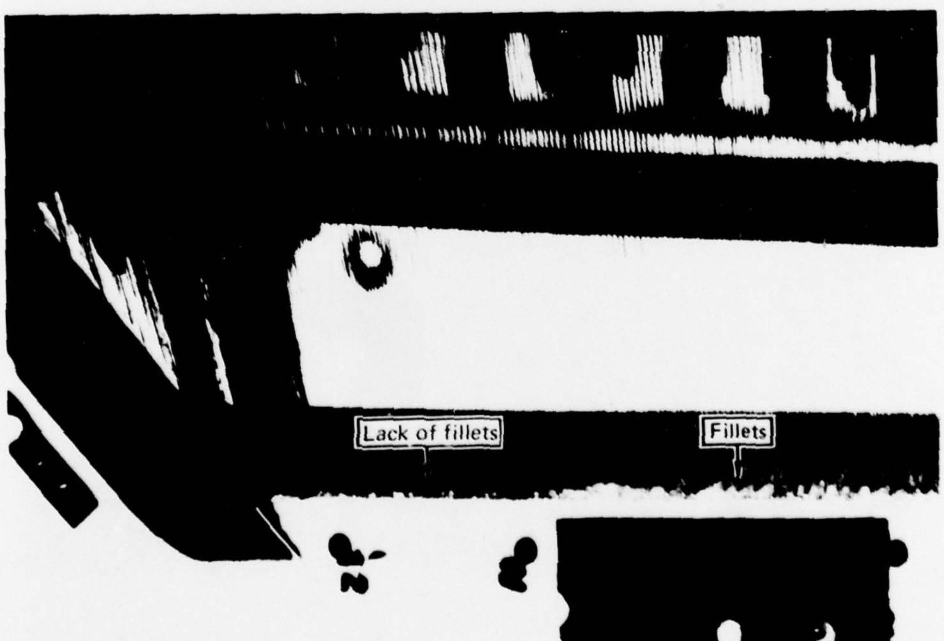


Figure 10-29.—Radiograph Showing Lack of Filleting

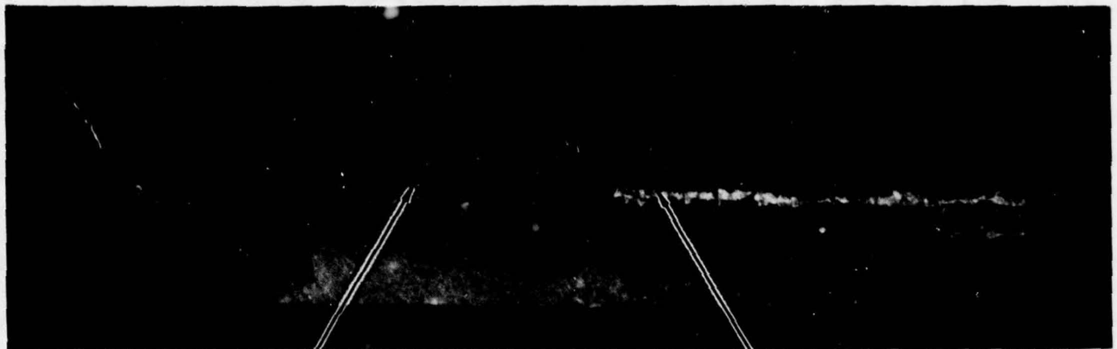


Figure 10-30.—Destructive Inspection Verifying Radiograph Indications

Neutron Radiography

Neutron radiography is a nondestructive inspection technique similar to X-radiography in that penetrating radiation is used to obtain visual images of the internal form of an object. Neutron radiography complements X-radiography because absorption characteristics of most elements are essentially reversed. Thermal neutrons are attenuated by light elements. As a result, nondestructive inspection can be made of light elements encased in or behind heavy elements. Neutrons highlight the adhesive material rather than the metallic structures seen by X-rays. A neutrograph of a void in an adhesive bondline is shown in figure 10-31.

Adhesive bonding defects detected by neutron radiography include adhesive voids and porosity, abnormal adhesive fillets, and water. As with X-radiography, neutron radiography will not directly determine bond strength, however, voids, resin-starved, and thick bondlines show as changes in the amount (mass) of the adhesive.

Available portable units using Californium-252 are capable of giving excellent results without requiring special facilities or preparation beyond that of an ordinary X-ray examination. The primary disadvantage of the method is the necessity for lengthy exposure times (in the order of 20 to 30 hours).

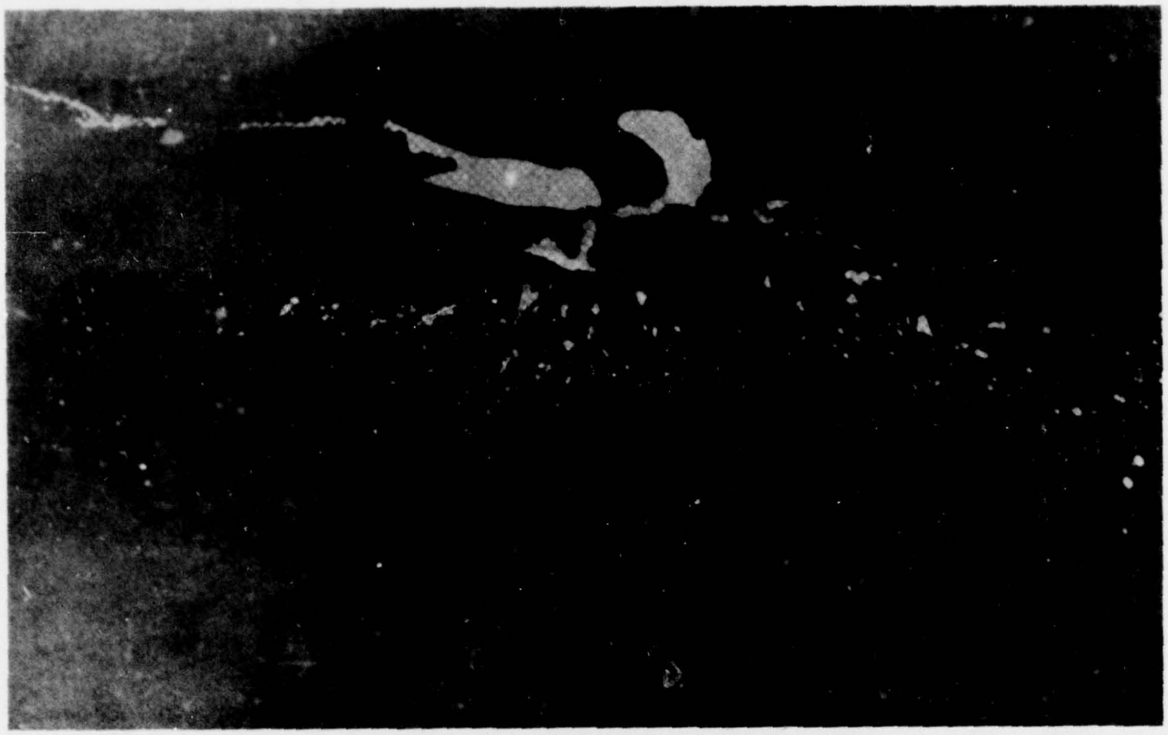


Figure 10-31.—Neutrograph of Voids in Adhesive Bondline

10.2.6 EDDY CURRENT

The eddy current inspection technique is applicable to the examination of electrically conductive material for the detection of irregularities in the structure. These irregularities may be either physical or metallurgical. The technique involves inducing eddy currents into the part. Their flow pattern is determined with a test coil and compared with a test standard. The technique is most effective for detecting irregularities near the surface. It can, however, be used for greater depths with decreasing sensitivity. The greatest advantages of the eddy current method are (1) it can detect, with minimum surface preparation, irregularities concealed by paint or by dirt embedded in a crack, and (2) it does not require a couplant.

The eddy current method is generally used for the detection of three types of defects These are:

- Cracks
- Faying surface and intergranular corrosion
- Heat damage

Cracks most commonly occur at fastener holes at panel edges. Typical locations are illustrated in figure 10-32.

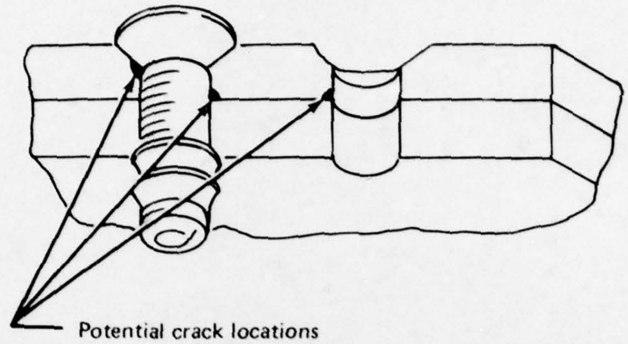


Figure 10-32.—Typical Locations of Cracks in Fastener Holes

Two inspection methods are available, either inspection from the surface or inspection of a hole with the fastener removed. The former method is illustrated in figure 10-33. It is a satisfactory method to detect the more gross cracks having a minimum length of roughly 0.25 inch. The crack may be detected effectively to an interface depth of 0.2 to 0.3 inch. This is dependent on the particular instrument and operating frequency.

Inspection for cracks in unfilled holes with a probe is illustrated in figure 10-34. The method is applicable to inspecting the edge of a panel that has been removed for repair. This procedure is more sensitive than the above. Cracks with lengths as low as 0.030 inch may be reliably detected.

Figure 10-35 shows the eddy current method being used to inspect for interface corrosion under body skins. It may also be used to detect damage to the metal caused by high heat exposure. This is accomplished by the instrument's ability to detect a change in the metal grain structure and conductivity.

The major limitation in applying eddy current inspection lies in the way the eddy currents are induced in the part. The small eddy current coil must be scanned over the area of interest, and in practice the effective inspection areasis approximately 3/16 inch in diameter. The time at each point may vary from 30 seconds to 5 minutes depending on the type of reading and instrument being used. For large surfaces this means a rather long inspection time. Other limitations are that the specific nature of the irregularities may not be clearly identified and inspection of ferromagnetic metals is sometimes difficult.

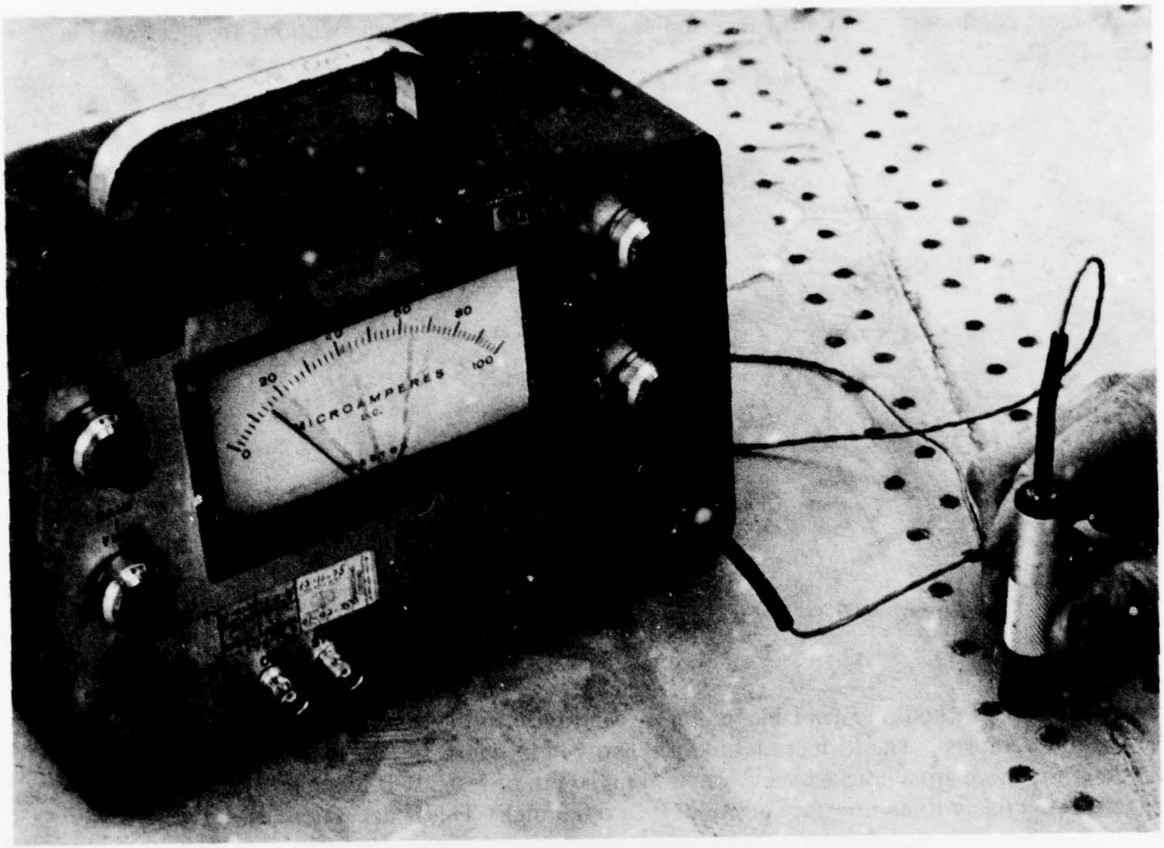


Figure 10-33.—Exterior Surface Eddy Current Inspection for Cracks in Fastener Holes

10.2.7 HOLOGRAPHY

Holography is a technique by which images are reconstructed or viewed through the interference of a reference beam with the inspection beam of a transmitted signal. This may be optical as in the case of laser holography or acoustical in the case of acoustic holography.

Acoustic Holography

Acoustic or ultrasonic holography is a newly developed technique for inspecting bonded structures. The system employs pulse echo ultrasonic techniques and focused transducers to "illuminate" the interior of a test part with sound. Scanning the part surface produces a "hologram" of the amplitude and position information from reflections within the part. The resulting hologram is then inserted into an optical reconstructor for viewing the part interior.

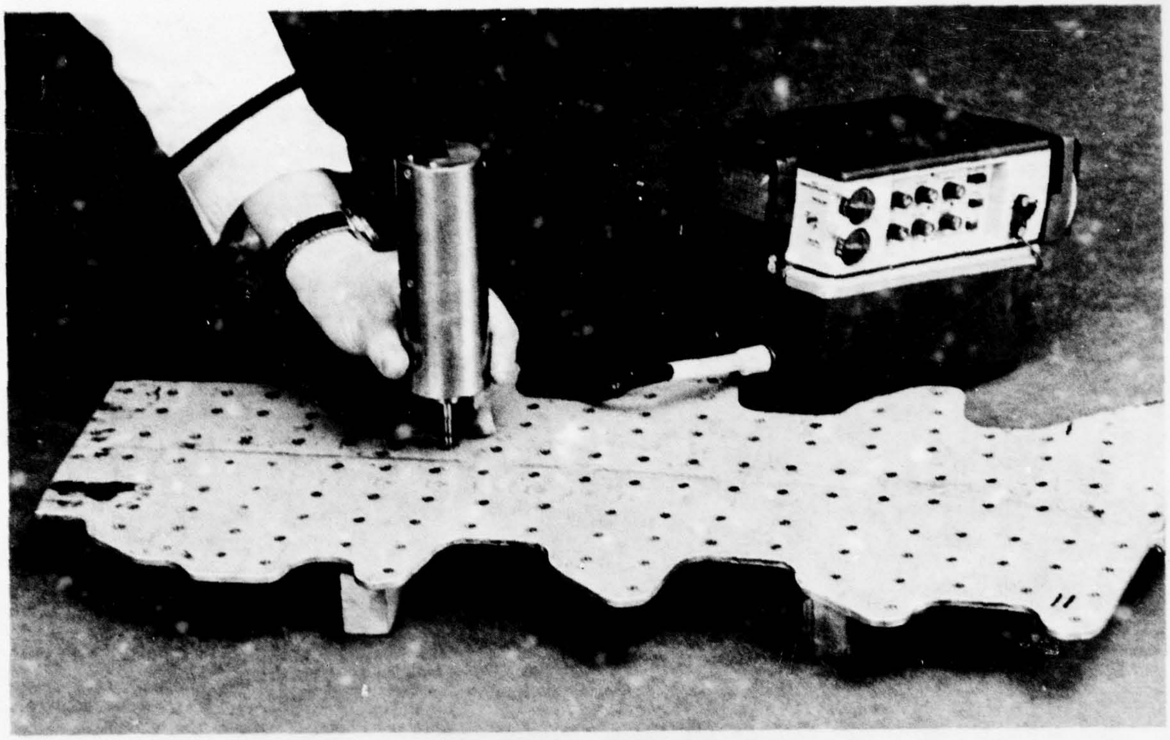


Figure 10-34.—Eddy Current Probe Inspection for Cracks in Fastener Holes

Optical Holography

Optical holography is a method of recording the amplitude and phase of the optical wavefronts reflected from an object such that, when reconstructed, these wavefronts have the relative amplitude and phase of the original wavefronts. Three-dimensional properties are contained in the image of the reconstructed wavefronts.

In practice a stress is applied to the part and a hologram made of the stressed area. Slight movement of the surface being viewed by holography during stressing may be detected and show as a defect in the bonded part.

The main limitation of optical holography is the necessity to isolate the part and inspection system from extraneous movement.

Figure 10-35.—Eddy Current Inspection of Fuselage Skins for Faying Surface Corrosion

10.2.8 THERMOGRAPHY

Thermal inspection is useful as a means of detecting bonding discontinuities directly beneath relatively thin, low thermal conductivity materials. For thermal inspection to be effective, a temperature gradient must be established in the face skin that can be measured or observed when the skin is heated or cooled after heating. Discontinuities appear as local temperature changes in the skin. The thermal conductivity difference between the face skins and the internal materials should ideally be large for the temperature changes to be monitored in real time. These changes may be detected by an infrared monitor or by test techniques employing substances that, when applied to the test surface, undergo physical or chemical changes in response to the temperature changes. The latter include: cholesteric liquid crystals, thermally quenched phosphors, thermally sensitive papers coated with organic pigments that melt over a small temperature interval, papers coated with a thermoplastic film containing microscopic air bubbles, papers coated with thermally sensitive dye precursors, and spray-applied dye precursors.

The liquid crystals and processes which produce thermally induced dye reactions have more practical application in bond inspection. The liquid crystals respond rapidly and reversibly to transient temperature changes and, when used by carefully trained personnel, they may be effective in conducting tests on relatively small areas. Large area inspection of flat or simply curved bonded structures is most easily performed thermally using temperature sensitive papers held by vacuum or adhesive backing against the test surface. The full-size thermograph obtained by this method is easily interpreted and may be preserved as a permanent record.

10.2.9 ACOUSTIC EMISSION

In some instances, acoustic emission techniques have been more effective than X-ray, eddy current, or conventional ultrasonics in detecting internal metal corrosion and moisture-degraded adhesive in honeycomb panels. The principle is based on the detection of sound- or stress-wave signals created by a material undergoing some physical or mechanical transformation. The equipment consists basically of an amplifier and a piezoelectric sensor with a resonant frequency in the low ultrasonic range (175 kHz). The emission level is recorded on a chart or meter. A visible light indicates when a predetermined emission threshold has been exceeded.

The process of scanning the inspection area is shown in figure 10-36. Simple heating methods employing a hot-air gun or heat lamp are used to increase emissions from active corrosion sources, and to create the stresses necessary to break moisture-degraded adhesive bonds.

Corrosion in aluminum honeycomb that was detected by acoustical emission is shown in figure 10-37. Figure 10-38 shows an area that was detected where moisture had destroyed the adhesive bond to the honeycomb core. This defective area was not detected by previous X-ray inspection because of the lack of standing water in the honeycomb.

Actual inspection results have shown that corrosion can be detected practically in honeycomb panels to a depth of 2 to 3 inches. Corrosion has been successfully monitored on the F-111 horizontal stabilizer in 8-inch honeycomb with 3/8-inch-thick skin.

The inspection scanning rate is quite rapid. After heating, normally 15 seconds or less is required to establish the presence or absence of active corrosion at a test location. Direct inspection cost savings of over 75 percent are claimed over comparative X-ray and ultrasonic techniques.

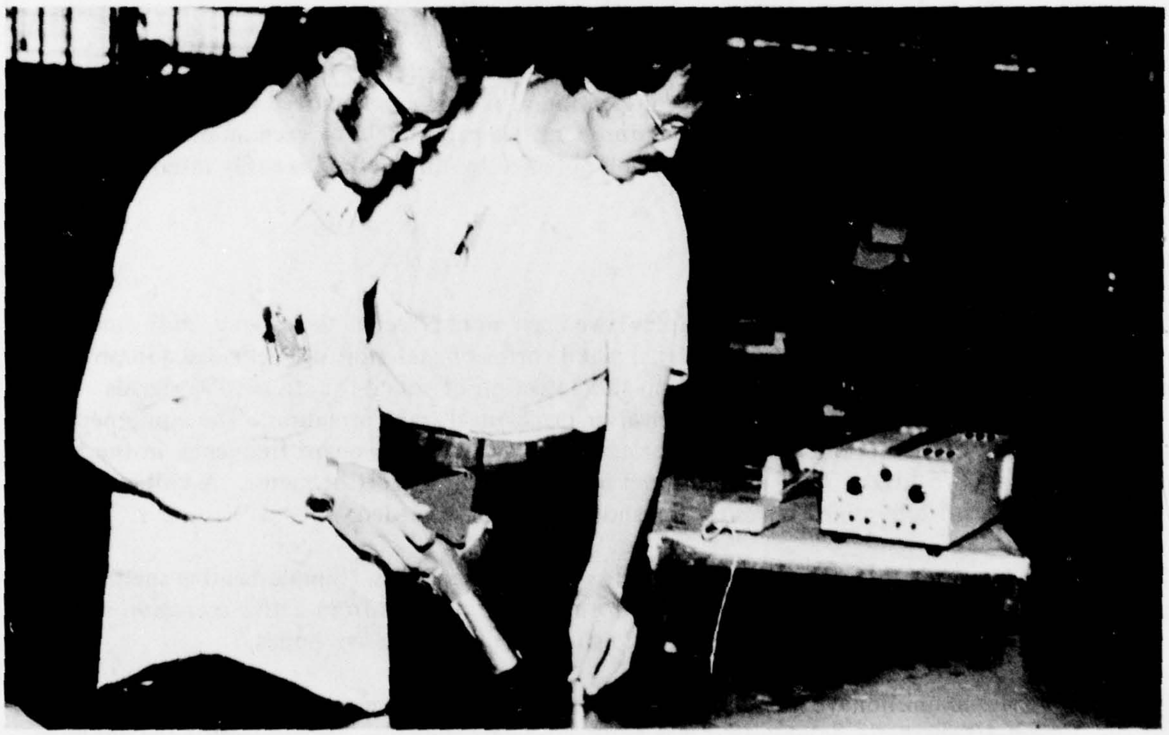


Figure 10-36.—Acoustic Emission Hand Scan Technique Using AETC Model 201 Signal Processor and Hot Air Gun Heating

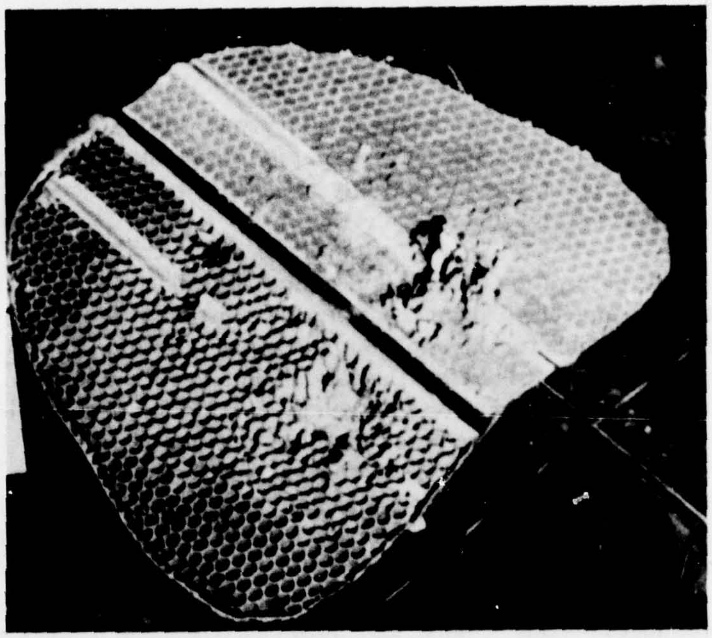


Figure 10-37.—Corrosion in Aluminum Honeycomb Core Detected by Acoustic Emission

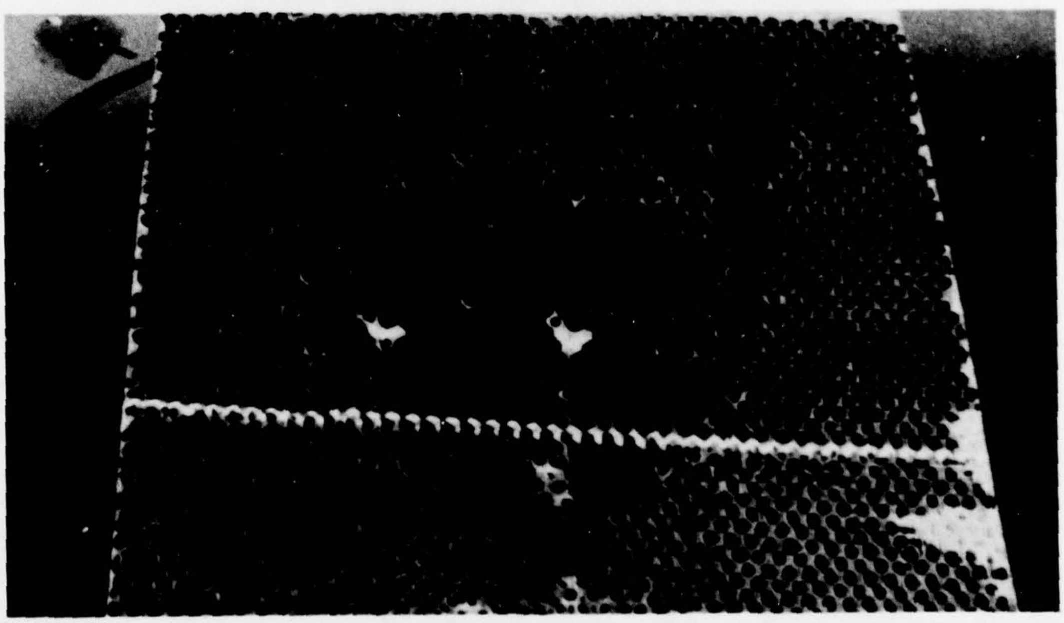


Figure 10-38.—Moisture-Degraded Area Detected by Acoustic Emission

The techniq... used to detect corrosion in aluminum honeycomb structure has been described by T. W. Rettig and M. J. Felsen in "Acoustic Emission Method for Monitoring Corrosion Reactions," NACE Journal, March 1974. This technique is briefly outlined below. However, a more precise procedure is being formulated at this time.

This test is based upon the observation that the application of heat accelerates corrosion of aluminum and results in an appreciable increase in acoustic emission. It is believed that the formation of hydrogen bubbles is responsible for this emission rate. An amplification of 90 to 100 db will permit monitoring this emission and therefore the detection of corrosion. The tools necessary to conduct this test are an Acoustic Emission Technology Corporation Model 201 Signal Processing System and a hot air gun. The panel to be tested is heated to about 65° C (150° F) by holding the hot air gun within 2-3 inches of the surface of the panel for about 15 seconds. The acoustic emission sensor is placed a short distance from the heated spot. The detector is held in position for 15 to 30 seconds after heating to obtain a complete record of any emission in the heated area. The inspection is carried out on a 15cm (6 inch) grid. An important consideration during the test is how the acoustic emission detector is held against the part surface. Since movement of this detector can produce appreciable noise, care must be exercised in its placement and holding. For this reason this test must be conducted by qualified NDE personnel.